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FLIGHT VIBRATION SURVEY OF F-100C-1 AIRCRAFT

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AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

This technical note was prepared in the Environmental Criteria Section, Environmental Branch, Engineering Test Division, Flight and Engineering Test Group, under Project 1309, Task 13004. The Project Engineer on this survey was Charles E. Thomas of the Environmental Criteria Section. The survey covered by this technical note is one of a series of programs conducted on operational aircraft by the Environmental Criteria Section. The flight tests were conducted at Wright-Patterson Air Force Base by pilots of the Fighter Branch, Flight Test Division, Flight and Engineering Test Group, during the period of 22 March 1957 to 24 May 1957.

The information garnered from this effort was submitted as raw data to the requesting agency upon completion of the tests, and is now being presented in a formal report for the purpose of wider distribution.

ABSTRACT

The F-100C-1 aircraft was surveyed to determine the vibration environment existing throughout the vehicle under all flight conditions expected in service. Approximately 34,053 data points were obtained from 17 separate locations on the vehicle during 17 test flights. The data obtained in this survey were evaluated to determine the vibration test requirements which should be specified for items of equipment to be used on the F-100C-1 aircraft. The data indicated that, in general, the vibration testing requirements listed in Specification MIL-E-5272 are more than adequate for F-100C-1 equipment, except in the 5 to 24 cps band.

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SECTION I

INTRODUCTION

The lack of sufficient data to define the actual dynamic environment in which the equipment within the vehicle operates is one of the major problems in airborne equipment design, application, testing, and use. In most cases this lack of data has resulted in either (1) overdesigning the equipment, with its attendant excessive development costs, time, specimen size, and weight, or (2) underdesigning the equipment, with a resulting lack of reliability and limited service life.

To provide the necessary information, the Environmental Criteria Section, Environmental Branch, Engineering Test Division, Flight and Engineering Test Group, has implemented a comprehensive data acquisition program aimed at obtaining vibration data on all available aircraft and missiles.

This is one of a series of reports which present vibration data measured on the structure of aircraft and missiles. The primary objective of these reports is the dissemination of important dynamics data to those concerned with developing airborne accessories. These data can be used as the basis for preparing design and testing specifications, for estimating environments on flight vehicles in the "drawing-board" stage, in establishing optimum location and installation practices, etc. The data in this report are interpreted only with respect to the specific vehicle under study, i.e., F-100C-1 aircraft; no attempt is made to assimilate this information with existing data on other similar vehicles or to present complete explanations of all the vibration phenomena involved. It is intended that later reports will be published to interpret the data and to draw comprehensive conclusions concerning vibration generation, propagation, structural response characteristics, and the like. However, the test instrumentation, procedures, and data reduction methods are covered in considerable detail.

SECTION II

DESCRIPTION OF THE F-100C-1 AIRCRAFT

The F-100C-1 Super Sabre, built by North American Aviation, Inc., is a single-place supersonic air superiority fighter. It is characterized by a 45° swept-back tail assembly with a low-set horizontal stabilizer, an oval nose air intake, and a pitot static boom extending from the nose. The airplane is powered by a turbojet engine equipped with an afterburner. The engine is a Pratt and Whitney J-57-F21 axial flow gas turbine engine having a rated sea-level static thrust of 10,200 lbs. and a maximum thrust of about 16,000 lbs. at maximum afterburner operation. The

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aircraft is equipped with tricycle type landing gear. Fuel is carried internally in fuselage tanks and externally in two 275-gallon drop tanks. The airplane has four 20-mm automatic guns. The guns are installed in the lower surface of the fuselage and outboard of the nose gear well, two on each side. The following specifications are applicable to the F-100C-1 aircraft, S.N. 53-1732.

TABLE I

F-100C-1 GENERAL SPECIFICATION DATA

Span	38 ft. 9 inches
Length (including pitot boom)	53 ft. 11 inches
Length (without pitot boom)	47 ft.
Height (to top of fin)	15 ft. 6 inches
Weight (clean)	24,970 pounds
Weight (with drop tanks)	28,950 pounds.

SECTION III

TEST INSTRUMENTATION

The test instrumentation comprised the following: (1) 48 MB Type 124 velocity pickups, (2) one Davies Laboratories, Inc., Model 501 14-channel magnetic tape recorder, and (3) one remotely controlled pickup selector switch. Generally, the pickups were mounted in groups of three and oriented to sense vibration along each of the three major axes of the aircraft. These pickups were attached to the aircraft structure and the engine at 17 points of interest. The locations are shown in Figure 1 of Appendix A. A more detailed description of the instrumentation is contained in Appendix A.

SECTION IV

TEST PROCEDURE

A total of 17 test flights was conducted during this survey. Vibration records were taken during all of the normal service conditions, such as: taxi, ground runup, takeoff, straight and level flight (at various altitudes, airspeeds, and power settings), turns, descent, landing, landing roll, formation flight, and with gunfire. Further information concerning the test procedure is contained in Appendix A.

The reels of recorded data were edited in the laboratory and each sample (approximately 5 seconds in length) was spliced into an endless loop. These loops were then placed on a Davies Model 502 tape playback system and a narrow bandwidth (10 cycles/sec.) analysis was conducted simultaneously on six of the twelve channels of data by using a Davies Model 510 heterodyne type analyzer.

The analyzed data were recorded on six modified Brown strip chart recorders in the form of a continuous spectrum of frequency (cps) versus transducer voltage (rms). The data points of interest were then extracted from the strip chart recordings, tabulated, and punched into IBM cards. Corresponding decks of "master cards" which contain detailed descriptive information concerning pickup locations, flight conditions, and source and order of vibration were also prepared. The extracted data and the appropriate descriptive information on the "master cards" were then processed by means of an ERA 1103A computer. Both the vibratory double amplitude expressed in inches and acceleration expressed in G units appear in the completed data card. The data were then sorted into the desired order and graphed by an automatic plotter having IBM card input capabilities.

SECTION V

PRESENTATION OF DATA

The plots contained in this report are: (1) summary plots for each individual pickup for all of the flight test conditions, (2) summary plots for each cluster (2 to 3) of pickups at any given test point, and (3) structural "zone" plots for all of the flight test conditions. It has been found that these types of data presentation are satisfactory for use in establishing specification requirements and in estimating vibration environments in other similar vehicles. However, in instances where a more detailed analysis of the vibration characteristics is required, it is possible to present graphs showing variations of many parameters affecting vibration conditions in the vehicles. For example, graphs can be made showing variation of vibration as a function of the following parameters: (1) Indicated Airspeed, (2) Altitude, (3) Engine RPM, (4) Flight Condition, (5) Engine Order, etc. Additional plots of this type can be provided if required. A more detailed description of data handling procedures, data analysis, and presentation methods is contained in Appendix A.

SECTION VI

RESULTS

During the 17 test flights conducted in this survey, 34,053 data points were obtained. With the exception of the gunfire condition, the following vibration envelope would be satisfactory for the F-100 aircraft:

5 to 14 cps	-	0.100 inches double amplitude
14 to 35 cps	-	± 1.00 g vibratory acceleration
35 to 80 cps	-	0.015 inches double amplitude
80 to 550 cps	-	± 5.00 g vibratory acceleration

This envelope exceeds the requirements of Procedure XII of Specification MIL-E-5272C in the low frequency range, but it is considerably below the levels of Procedure XII in the higher frequency ranges. During gunfire and throughout the frequency range of 20 to 500 cps, the levels of vibration increased significantly, especially in the forward quarter of the fuselage. At the fundamental frequency of the gunfire, double amplitudes up to 0.100 inches were encountered. In the frequency range of 150 to 250 cps, vibratory accelerations considerably above ±10 g were measured. Although the effects throughout the remainder of the aircraft were noticeable, they were considerably lower due to the transmissibility characteristics of the structure.

With the exception of the forward quarter of the fuselage, the vibration produced by the engine was detected in significant levels throughout the entire aircraft. As expected, the engine-produced vibration was of the discrete frequency type.

In the case of the shock-mounted equipment, the vibration at the fundamental of the gunfire frequency was not attenuated. This can probably be attributed to the fact that this frequency range falls on that portion of the isolator resonance curve where the transmissibility is equal to or greater than unity. The equipment was very well isolated above this frequency range.

SECTION VII

CONCLUSIONS

The levels of vibration required by Procedure XII of Specification MIL-E-5272C are inadequate in the very low frequency range and too conservative at the higher frequencies for use in the resonant endurance tests on F-100 equipment. However, in order to compensate for the severe environment produced by gunfire, a frequency sweep type test, using levels considerably above Procedure XII requirements, would be desirable for detecting malfunctions which might occur during gunfire.

APPENDIX A

1. Instrumentation

MB Manufacturing Company Type 124 velocity pickups were mounted in clusters (generally three) at 17 separate test points on the aircraft engine and structure. The locations are summarized in Table II and shown in Figure 1. The Type 124 velocity pickup has the following characteristics:

Nominal sensitivity	96.4 mv (rms)/in/sec(rms)
Usable frequency range	5 to 2000 cps
Temperature range	-50 to +250°F

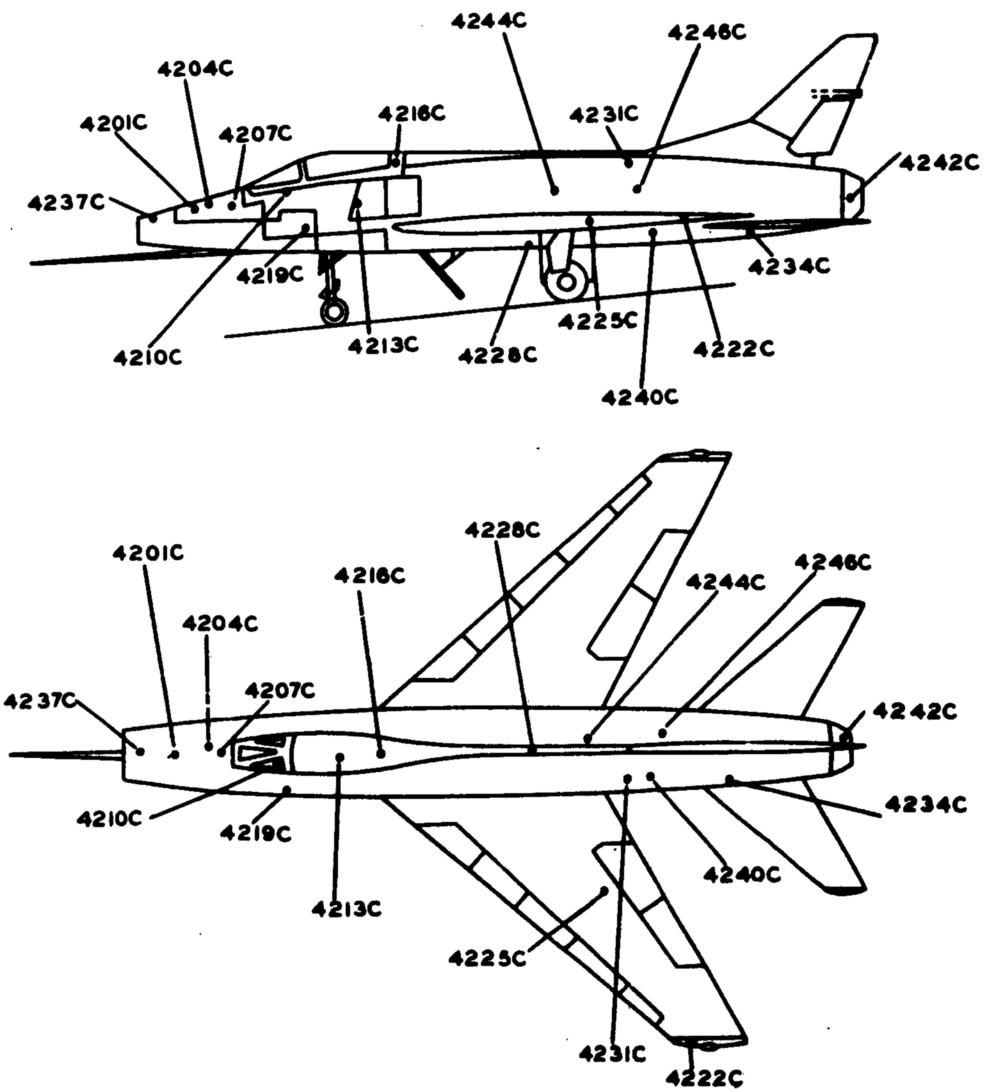

Figure 1. Schematic Presentation of Pickup Locations

TABLE II

PICKUP LOCATIONS

PUID	Location	Direction	PUID	Location	Direction
01	Nose Section Structure Sta. 47	Vert.	25	Rear Wing Spar	Vert.
02		Lat.	26		Lat.
03		F/A	27		F/A
04	Type A-4 Sight Amplifier	Vert.	28	Structure, Bottom Center,	Vert.
05	(Shock Mounted) Sta. 72	Lat.	29	Sta. 302	Lat.
06		F/A	30		F/A
07	Right 263-ARC-34 Unit	Vert.	31	Structure, Top Left Side	Vert.
08	(Shock Mounted) Sta. 89	Lat.	32	Sta. 355	Lat.
09		F/A	33		F/A
10	Instrument Panel, Upper Left Side	Vert.	34	Structure, Lower Left Side	Vert.
11	(Shock Mounted) Sta. 128	Lat.	35	Sta. 490	Lat.
12		F/A	36		F/A
13	Structure at Base of Pilot Seat Aft	Vert.	37	Accessory Pad on Nose of Engine	Vert.
14	Sta. 175	Lat.	38		Lat.
15		F/A	39		F/A
16	Structure at Base of Main Inverter	Vert.	40	Brush Band of 400 A D.C. Gen.	Vert.
17	Sta. 200	Lat.	41		Lat.
18		F/A			
			42	Aft End of Engine Burner Section	Vert.
19	Structure, Lower Left Side	Vert.	43		Lat.
20	Sta. 147	Lat.			
21		F/A	44	Forward End of Forward Compressor	Vert.
			45	Section	Lat.
22	Left Wing Tip	Vert.			
23		Lat.	46	Aft End of Rear Compressor	Vert.
24		F/A	47	Section	Lat.
			48		F/A

A typical response curve is shown in Figure 2. The three-position mounting blocks used to attach the pickups to the vehicle structure have no resonances below 500 cps.

A Davies Model 501 14-channel magnetic tape recorder was used to record the outputs of the vibration pickups. The recorder, complete with control box and shock mount, and the pickup selector switch were installed in the nose section of the aircraft. The 26- to 28-volt DC power required for operation of the recorder and the selector switch was obtained from the aircraft DC system. The recorder was preset for a recording time of five seconds. The Model 501 recorder was an FM type having the following characteristics: (1) FM carrier frequency of 10 KC, (2) intelligence frequency response of 3 to 2000 cps, (3) dynamic recording range of 45 db, (4) tape speed of 15 inches per second, (5) total recording time of approximately 8 minutes, (6) weight of 55 lbs., and (7) overall dimensions, including shock mount, are 10-1/2 inches x 11 inches x 21 inches. The twelve data channels had an input impedance in excess of 100,000 ohms. The thirteenth channel had an input attenuation of approximately 45 to 1 and was designed for direct connection to the engine tachometer generator. The fourteenth channel was used to record the output from an internal ODKC (crystal

controlled) oscillator. This channel was used during tape playback to control the playback speed by means of a servo, and it was also utilized in the electronic compensation of the tape playback and analysis system. The recorder used 1-3/4 inch wide magnetic tape in 400- to 600-foot reels.

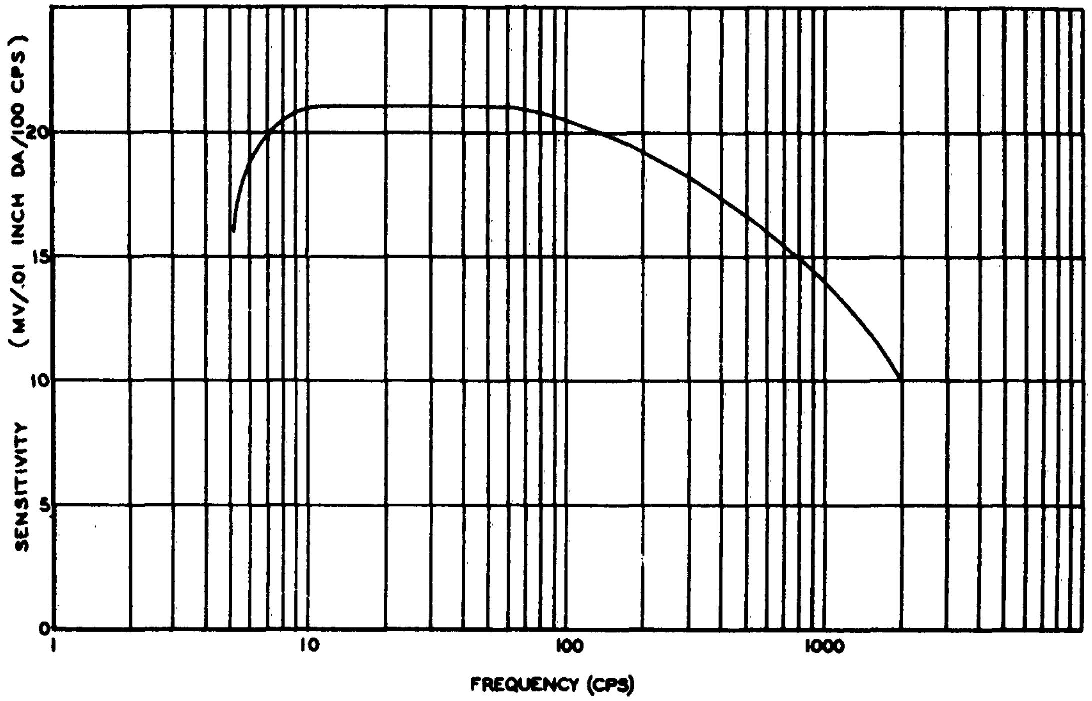

Figure 2. Frequency Response of MB Type 124 Vibration Pickup

2. Test Procedure

A total of 17 test flights was flown during this survey. A summary of the test conditions experienced is shown in Table III. The test plan was based on requirements of interested laboratories at WADD and on information obtained from USAF flight test pilots. Data were obtained during all of the normal operational configurations which the aircraft could be expected to encounter. These configurations included formation flying to evaluate the effects of one aircraft on another in close formation. It also included gunnery missions to determine the effects of the intense vibration produced by gunfire. Test conditions were also established which permitted the evaluation of such variables as altitude, indicated airspeed, engine thrust at constant airspeeds and altitudes, the effects of using the speed brakes, gear, and other control surfaces at various airspeeds. Prior to each flight, the test pilot was thoroughly briefed on the desired flight test conditions and was given the appropriate flight test data card. As soon as the desired flight test condition was achieved, the output of each of the 48 pickups was recorded in successive groups of twelve each. This was done by means of a remotely controlled selector switch. A total of 944 records was made during the 17 test flights. The reels of recorded data were returned to the laboratory for analysis.

TABLE III

FLIGHT CONDITIONS FOR F-100C-1

Code	Test Condition
01	Taxi
02	Ground Runup (Clean)
03	Takeoff Roll
05	Takeoff (with Afterburner)
06	Climb (Normal)
07	Cruise (Normal)
08	Cruise Speed Brakes Extended
09	Cruise with Gunfire
25	Touchdown
26	Landing Roll
29	Cruise (Turbulent Air)
48	Cruise (with Afterburner) Clean

3. Data Processing

The reels of tape were edited and each 5-second record was spliced into a continuous loop and properly labeled. These records were analyzed by means of a Davies Model 510 automatic analyzer, which was used in conjunction with a Davies Model 502 magnetic tape playback system. The complete playback and analysis system is shown in Figure 3.

The Model 502 magnetic tape playback system had been modified to provide playback at either 15 or 30 inches per second. The tape playback contained a servo control system which permitted playback of the tape at its originally recorded speed within very close tolerances. During playback, the output from all fourteen tracks was fed simultaneously into the fourteen FM playback discriminators. The output signal from each of the twelve data channels was a 1 to 1 reproduction of the original analog signal.

An important feature of the playback system, i. e., electronic compensation, should be discussed briefly at this point. During the data recording process, the input of the number 7 track (channel) on the tape was the voltage from a very stable, crystal-controlled reference-frequency oscillator which was contained within the recorder. During playback, a portion of this 10KC signal was fed into a standard FM discriminator channel. Assuming there were no wow and flutter during playback, the output voltage from this particular discriminator (Channel 7) would have been zero. Therefore, if any voltage were obtained from this channel during playback, it would have been an "error" voltage produced by wow and flutter.

Figure 3. Automatic Tape Playback and Analysis System Equipment

This "error" voltage, with its phase shifted 180°, was fed simultaneously into the output stage of each of the twelve data channels. In this manner, the extraneous voltages due to wow and flutter were eliminated from the signal output of the data channels. Prior to playback of data, each of the data channels was adjusted for optimum cancellation (approximately 40 db). Hence, an overall dynamic range of 45 db (record through playback) could be maintained consistently. Table IV contains a summary of pertinent facts pertaining to the Davies Model 502 magnetic tape playback system and the Davies Model 510 automatic wave analyzer.

The Davies Model 510 automatic analyzer is a constant bandwidth heterodyne analyzer complete with a motor-driven variable frequency oscillator. The system has six separate analyzers and can simultaneously analyze six data channels. Both the oscillator scanning rate and the analyzer bandwidth are adjustable over the following limits:

(1) Scan rate 0.3 to 3.0 cps/sec (2) Bandwidth 1 to 40 cps

TABLE IV

SPECIFICATIONS FOR DAVIES LABORATORIES MODEL 502 MAGNETIC TAPE PLAYBACK AND MODEL 510 AUTOMATIC ANALYZER

Frequency Range	3 cps to 2,000 cps
Frequency Accuracy	0.2 cps from 3 to 40 cps 0.5% from 40 to 2,000 cps
Input Voltage Range (2-position switch)	1.0 volt or 10 volts rms maximum
Amplitude Accuracy	5% of reading or 0.2% of full scale
Selectivity	Narrow Range - continuously variable from 1/2 to 8 cps Broad Range - continuously variable from 8 to 45 cps
Scanning Speeds, Motor Drive	Speed Range 25:1 - continuously adjustable Minimum Sweep Time - 15 minutes Maximum Sweep Time - 6 hrs. and 15 min.
Recorder Speed of Response	2 seconds for 90% full scale
Tape Speed	15 or 30 inches per second
Loop Length	Approx. 2-1/2 ft. to at least 75 ft.
Tape Width	1 and 1-3/4 inch

The output of the six wave analyzer channels was fed into six modified Brown strip chart recorders. A continuous spectrum plot of frequency (cps) versus voltage (rms) was produced by the strip chart recorders. The chart speed was servo controlled and could be varied from 0.08 inches per minute to 13.5 inches per minute. The voltage was plotted on a logarithmic scale, and the time required for full scale deflection, i.e., zero to one volt, was approximately two seconds. A sample analysis of a 100 cps square wave is shown in Figure 4.

In selecting the bandwidth to be used in an analysis of this type, one must consider the following: (1) the frequency resolution desired, (2) the rate of scan, (3) the length of the data sample, (4) the time available for data analysis, (5) the quantity of data to be analyzed, (6) the type of data being analyzed, and (7) the type of presentation of the completed data. Based on a consideration of these variables, a bandwidth of ten cycles per second was selected for these analyses.

Following the harmonic analysis, the Brown strip chart recordings were edited and the voltage peaks of interest were marked. Each of these peaks constitutes a data point. The corresponding values of frequency and voltage for each of these peaks were tabulated and, subsequently, punched into IBM cards. Each data point was recorded on a separate card. Then these cards were processed through the ERA 1103A computer at the rate of ninety cards per minute. Prior to processing each set or flight of data cards through the computer, a series of three sets of

"master cards" was prepared and fed into the computer. These sets of "master" cards are:

(1) the "flight condition masters" which contain all of the necessary flight parameters, i.e., altitude, IAS, power, etc., associated with each of the data cards. This information is obtained from the flight test data card.

(2) the "pickup location masters" which contain the information required to identify each data point for each channel and record number with a particular pickup.

(3) the third set of "masters," which are known as the "source and order masters," contain sufficient information to identify specific vibration frequencies with known orders of engine and propeller unbalance and also blade passage frequencies of the propeller or rotor blades, as the case may be.

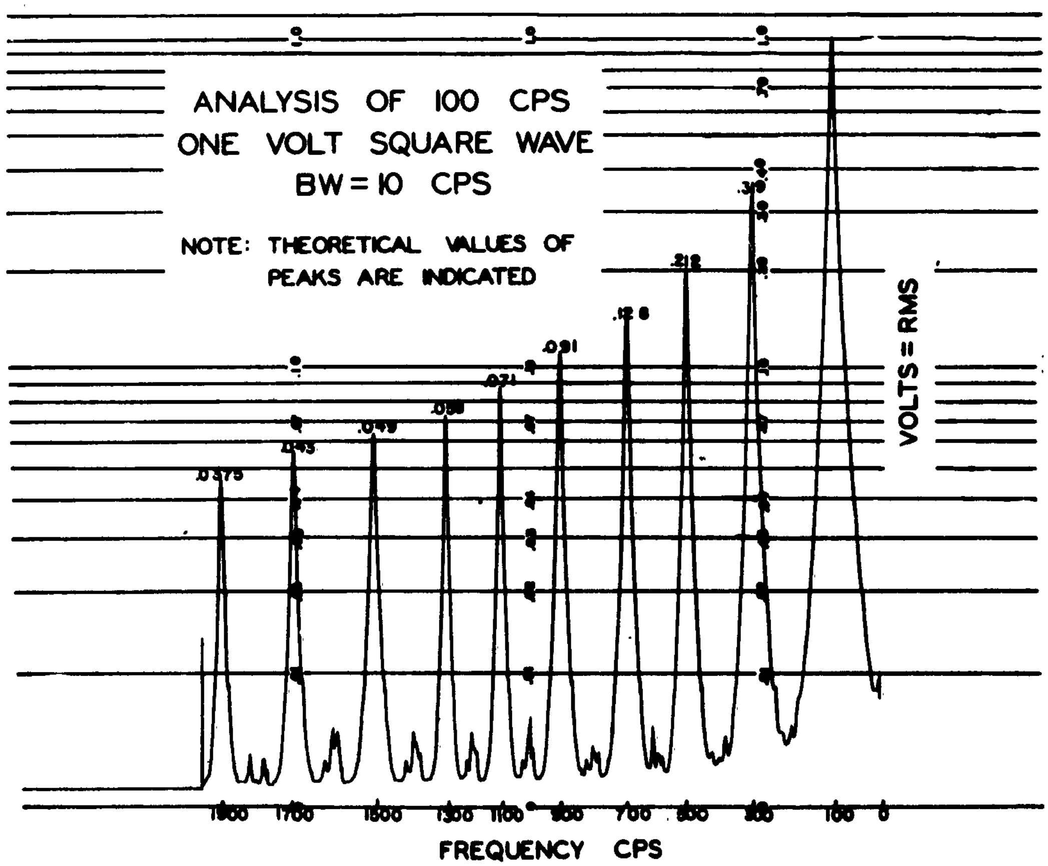

Figure 4. Analysis of 100 cps One Volt Square Wave

As the data cards were processed, a new and complete "answer" card having the following information was produced: the computed values of double amplitude in inches, acceleration in g's, log of frequency, log of double amplitude, log of acceleration, all of the data on the original data card, and all of the appropriate data obtained from the "master" cards.

After the computations were completed, all of the data cards were arranged in the desired sequence by means of an IBM sorter. Then a multi-copy IBM listing was made of all data. These listings were used in detail studies of the data and in checking the accuracy of the completed graphs.

Automatic plotters, utilizing IBM card input, were used to plot the graphs of frequency in cycles per second versus vibratory double amplitude in inches. The plotting rate for the plotters used in these tests ranged from 30 to 60 points per minute. The three types of graphs plotted were:

(1) summary (all test conditions) plots for each individual vibration pickup,

(2) summary plots for each cluster (2 or 3) of pickups,

(3) summary plots for each "structural zone."

In all three types, all of the data obtained on the 17 test flights were plotted. No plots were made to indicate the effects of variables, such as power, altitude, IAS, etc. Plots of this type can be obtained upon request.

The Type 1 graphs permit a detailed study of the vibration characteristics at a particular location in the test vehicle along a single axis.

The Type 2 graphs present the overall vibration environment, measured under all test conditions, at each of the 17 test points. Generally, this includes all data obtained from the 2 to 3 pickups in each cluster.

Where the overall vibration environment for a generalized structural zone, e. g., front quarter of the fuselage, is desired, the Type 3 graphs are most useful. The structure of the test vehicle has been arbitrarily divided into nine major areas. Each of these major areas has been further subdivided into the following three categories: (1) vehicle structure, (2) rigidly mounted equipment, and (3) shock-mounted equipment. A complete listing of these "structural zones" is contained in Table V.

All graphs are log-log (3 x 5 cycle) plots of frequency versus double amplitude vibration. As indicated previously, the log of frequency, double amplitude, and acceleration were computed during the computational phase of data reduction. This is required to permit the automatic production of plots of frequency versus double amplitude on a log-log scale. The standard automatic plotters available will not accept linear input and then plot on a log scale. Therefore,

by using the proper scale factors, the logarithms of the variables to be plotted can be adapted to any standard plotter input and the resultant graphs will be log-log plots of the original data. On log-log plots of frequency versus double amplitude, levels of vibratory acceleration appear as straight lines of constant slope. Reference values of ±0.5, ±1.0, ±5.0, and ±10.0 g have been included on all graphs. This permits simultaneous readings of double amplitude and acceleration at any given frequency. A more detailed description of the data reduction processes used to reduce the vibration data is contained in WADC TN 59-44, ASTIA Document No. AD 210478, dated February 1959, and titled "Data Reduction Techniques for Flight Vibration Measurements."

TABLE V

CODE FOR STRUCTURAL ZONE OF A/C

Code Nr.	Structural Zone
01	Forward Quarter of Fuselage
02	Center Half of Fuselage
03	Aft Quarter of Fuselage
04	Vert. & Horiz. Stab. Incl. Rudder & Elevators
05	Outer one-third of Wing
06	Inner two-thirds of Wing
07	Engine
08	Rigidly Mounted Equipment in Forward Quarter of Fuselage
09	Rigidly Mounted Equipment in Center Half of Fuselage
10	Rigidly Mounted Equipment in Aft Quarter of Fuselage
11	Rigidly Mounted Equipment in Vert. & Horiz. Stab. Incl. Rudder & Elevators
12	Rigidly Mounted Equipment in Outer one-third of Wing
13	Rigidly Mounted Equipment in Inner two-thirds of Wing
14	Rigidly Mounted Equipment in Engine
15	Shock Mounted Equipment in Forward Quarter of Fuselage
16	Shock Mounted Equipment in Center Half of Fuselage
17	Shock Mounted Equipment in Aft Quarter of Fuselage
18	Shock Mounted Equipment in Vert. & Horiz. Stab. Incl. Rudder & Elevators
19	Shock Mounted Equipment in Outer one-third of Wing
20	Shock Mounted Equipment in Inner two-thirds of Wing
21	Shock Mounted Equipment in Engine
22	Engine Accessory Section
23	Main Rotor Transmission Case
24	Rigidly Mounted on Engine Accessory Section
25	Rigidly Mounted on Main Rotor Transmission Case
26	Shock Mounted on Engine Accessory Section
27	Shock Mounted on Main Rotor Transmission Case

4. Results

A total of 944 records and 34,053 data points was obtained on the 17 test flights. In general, the data cover the 5 to 550 cps frequency range rather thoroughly. The discussion of the data contained in this report is limited to a consideration of the aircraft by structural zones. However, graphs are included for each of the 48 individual pickups and for each of the 17 different test points. The use of the structural zone breakdown suffices for the purpose of this report.

As indicated in the section of this report which describes the methods of data presentation, the structure of the aircraft has been divided into nine zones. These, in turn, have been subdivided into three divisions: (1) structure, (2) rigidly mounted equipment, and (3) shock-mounted equipment. With three exceptions, all structural zone plots in this report are for data obtained on the aircraft structure.

Figure No. 5 shows the data obtained on the structure of the forward quarter of the fuselage. The data are rather evenly distributed over the entire 5 to 500 cps frequency range. In the 5 to 20 cps range, most of the data are considered to be due to high-speed flight through turbulent air. The cluster of data points in the 20 to 30 cps frequency can be attributed to gunfire since the fundamental gunfire frequency is nominally 1500 rounds per minute or 25 rounds per second. The scatter of data is due to the fact that all of the guns do not fire at exactly the same rate and several of the guns were changed during the course of the test. Detailed analysis of the data indicated that gunfire was the source of all data points having double amplitudes above 0.010 inches in this frequency range. The distinguishable cluster of data points in the 50 to 60 cps band can be attributed to the first harmonic of the fundamental (25 cps approximately) gunfire frequency.

Above the 60 cps region, there are no particular clusters of data which are significant. In general, it was found that the maximum level of vibratory acceleration encountered in the range above 60 cps without gunfire was less than ± 5 g's. However, with gunfire, this level was raised above ± 20 g's in the vicinity of 200 to 250 cps. An acceleration level of ± 5 g's was exceeded quite frequently over the 90 to 500 cps frequency range.

Figure No. 6 shows the vibration data measured in the center half of the fuselage. Again, the two clusters of data appear at 20 to 30 cps and at 45 to 55 cps. These clusters can be attributed to the fundamental and the first harmonic of the gunfire frequency. The levels in general are approximately one-fifth as high as those encountered nearer the guns in the forward quarter of the fuselage. This is especially true of the higher frequencies (above 60 cps). This reduction in level can be attributed to such things as structural attenuation and the more rigid and more massive structure in the center section of the aircraft. Upon close inspection of Figure 6, clusters of data can be distinguished near the following frequencies: (1) 100 cps, (2) 150 cps, (3) 200 cps, (4) 300 cps, and (5) 500 cps. These are due to engine unbalance and can be related directly to

the fundamental and harmonics of the rotational speed of both the high- and low-speed rotors. With few exceptions, the upper level of acceleration, measured in the fuselage center section, is ±2.5 g's.

Figure 7 shows the vibration measured in the aft quarter of the fuselage structure. Again, considerable low frequency (5 to 10 cps) vibration having double amplitudes in excess of 0.10 inches was encountered. As expected, the effects of gunfire are considerably less in the aft quarter of the fuselage than was encountered farther forward in the structure. However, the effects of the vibration produced by the engine were more pronounced in the 150 to 300 cps region. Although the overall level was not increased appreciably, a greater number of data points was obtained above the ± 2.5 g level.

Figure 8 shows the vibration measured on the outer one-third of the wing. A few isolated cases were encountered with double amplitudes above 0.20 inches in the 5 to 20 cps range. The data in the 15 to 20 cps region can be attributed to the wing tip's response to turbulent air. The reduced effects of gunfire are evident in the 20 to 30 cps frequency range. Although the clusters of data are not sharply defined, the engine appears to be the dominant source of vibration in the 50 to 500 cps. In most cases, the response measured on the wing is greater than that encountered on the engine itself. This is especially true of the peak in the vicinity of 100 cps. As indicated on the graphs, the response of the wing tip is approximately twice that of the engine.

Figure 9 shows the data measured on the inner two-thirds of the wing. With the exception of the very low frequencies, i. e., 5 to 10 cps, the vibration encountered on this portion of the wing is considerably below that measured on the structurally light outer one-third of the wing. In general, the overall level of vibration is below one g in the 5 to 200 cps range. In the 200 to 500 cps range, most of the vibration was less than 2.5 g's. The effects of gunfire, i. e., 20 to 30 cps, and the fundamental of the low-speed rotor, i. e., 90 to 100 cps, are quite evident on the structurally rigid inner two-thirds of the wing.

Figure 10 shows the vibration measured on the engine. This data was obtained from approximately ten pickups located at various test points on the engine. With the exception of the low-frequency vibration due to turbulence and that due to gunfire, the vibration encountered on the engine was of the discrete frequency type and could be related to specific multiples of the high- and low-speed rotor. The cluster in the 70 to 100 cps region was due to the fundamental of the low-speed rotor. The second order of the low-speed rotor accounts for the cluster of data in the 200 to 230 cps range. The concentration of data in the 130 to 165 cps region is due to the first order of the high speed rotor. The data in the 270 to 320 cps range could be attributed to both the third order of the low-speed rotor and the second order of the high-speed rotor. However, past experience with other J-57 engines indicates that the vibration in the 270 to 320 cps range is most likely to be due to the second order of the high-speed rotor. This is also the case with the cluster of data in the 450 to 520 cps range, it being due to the third order of the high-speed rotor. For the most part, the level of

vibration encountered on the engine was below ± 2.5 g's. However, there were a few data points in the 200 to 300 cps range which approached a level of ±5 g's. The vibration of the low-frequency rotor appeared to reach a peak at the maximum engine rpm. However, as has been experienced in the past, the maximum vibration due to the high-speed rotor occurs at considerably less than maximum rpm. The peak condition which occurs at approximately 150 cps occurs at an engine rpm of approximately 94% which is well within the cruise range of the F-100C aircraft.

Figure 11 shows the vibration measured on shock mounted equipment in the forward quarter of the aircraft fuselage. As expected, there is considerable low-frequency vibration (5 to 20 cps). This can be attributed to turbulence and the fact that the shockmounts do not isolate appreciably over most of this range. The 20 to 25 cps vibration is due to gunfire which is not greatly attenuated by the shockmounts in this frequency range. Above 25 cps there are no particular concentrations of the data, most of which have levels below ± 2 g's. The few cases which exceeded the ± 2-g level occurred during gunfire. The unexpectedly high transmission of vibration above 50 cps can possibly be attributed to the fact that the isolators were either "bottoming" or very nearly so due to resonant response of the isolator. This would result in increased transmissibility during that period.

Figure 12 shows the vibration measured on shock mounted equipment in the center half of the fuselage. For this report, data were obtained only from the shock mounted instrument panel. Although the low-frequency data, due mostly to turbulence, are still evident, the effects of gunfire are much less than were encountered in the previous case. This can be attributed to decreased transmissibility of the structure and the more efficient shock mounting system. The cluster of data in the 45 to 52 cps range is the instrument panel response to the panel vibrator. No complete explanation was found for the data above ±1 g in the 350 to 450 cps range. This is the region in which the panel vibration isolators should be performing efficiently. Further, the possibility of electrical pickup was discounted because of the very low impedance type of pickup used for these tests. One possible explanation is that the response is due to a localised panel resonance which requires a very low level of excitation.

Figure 13 shows the vibration encountered on the engine accessory section. The low level of low-frequency (5 to 10 cps) vibration can be attributed to the fact that the accessory section is located very near the center of the aircraft, where the low-frequency vibration was found to be at a minimum. The effects of gunfire, as expected, are considerably reduced because of the mass of the engine to which the accessory case is attached and the increased attenuation due to structural flexibility. The cluster of data in the 80 to 100 cps region can be attributed to the fundamental frequency of the low-speed rotor. The fundamental of the high-speed rotor is the source of the cluster of data in the 130 to 160 cps range. The absence of an appreciable second order of both the high- and low-speed rotor is probably due to the flexibility of the connection between the accessory section and the engine. The third order of the high-speed rotor is the source of the cluster of data in the 450 to 500 cps range. With the exception of the cluster of data in the

80 to 100 cps range, the level of high-frequency (above 50 cps) vibration is below ±2.5 g's. The maximum level attained in the 80 to 100 cps region was approximately ± 4 g's.

Figure 14 shows the vibration measured on the rigidly mounted equipment on the engine accessory section. The effects of gunfire are quite evident in the 20 to 30 cps frequency range. The large peaked concentration of data in the 80 to 100 cps range is due to the resonant response of the generator-accessory section combination. Although the generator solid-block resonance is above 200 cps, the combination of the generator with the more flexible mounting pad on the accessory section results in a much lower resonant frequency. Also in evidence is the first, second and third order of the vibration produced by the high-speed rotor of the engine. The level of the first order is generally higher than the second and third orders. The concentration of data in the 170 to 200 cps range can be attributed to the second-order vibration of the engine's low-speed rotor.

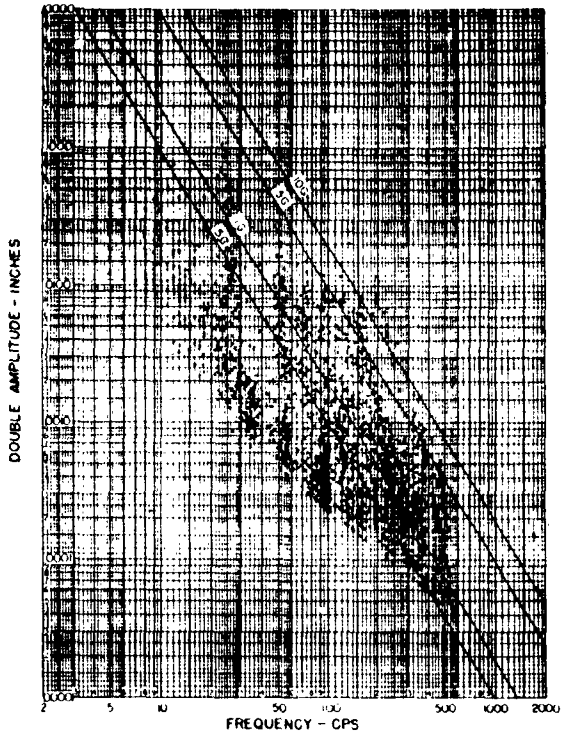

Figure 5. LOCATION: FORWARD QUARTER OF FUSELAGE

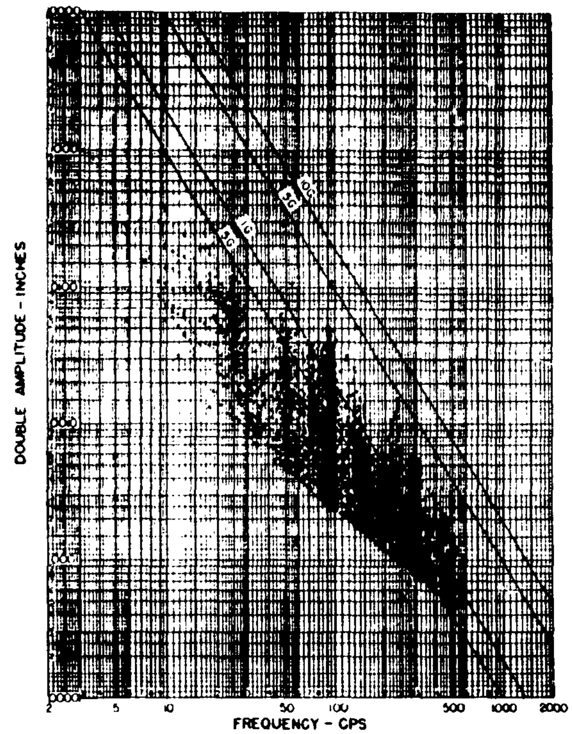

Figure 6. LOCATION: CENTER HALF OF FUSELAGE

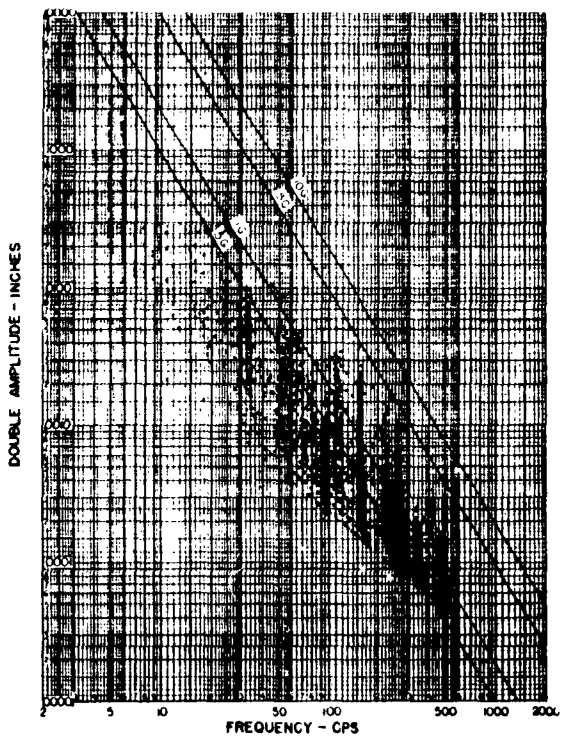

Figure 7. LOCATION: AFT QUARTER OF FUSELAGE

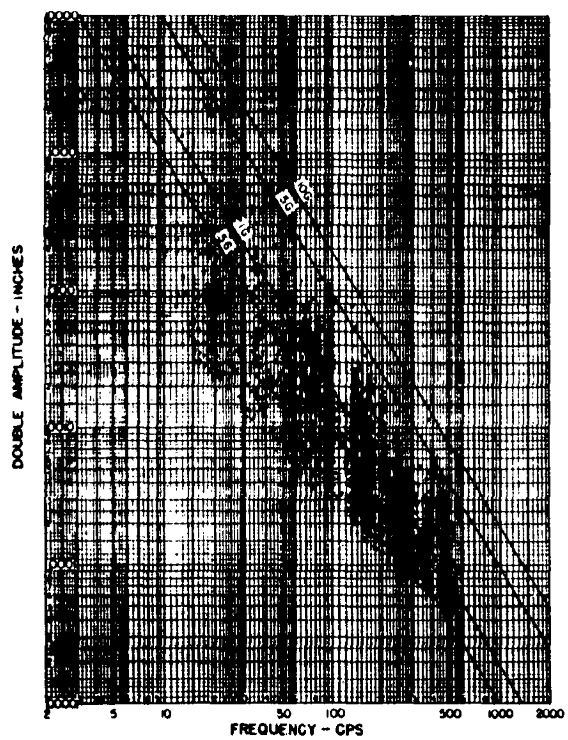

Figure 8. LOCATION: OUTER ONE-THIRD OF WING

Figures 5 to 8. Summary Plots for Structural Zones

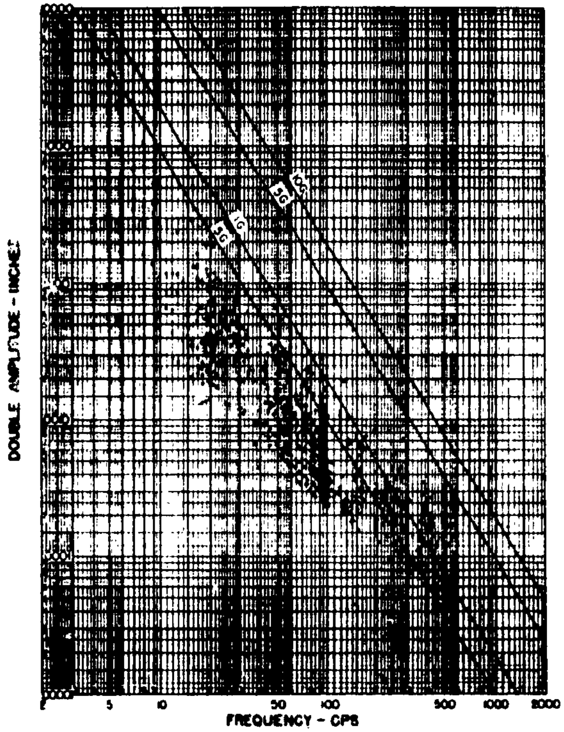

Figure 9. LOCATION: INNER TWO-THIRD OF WING

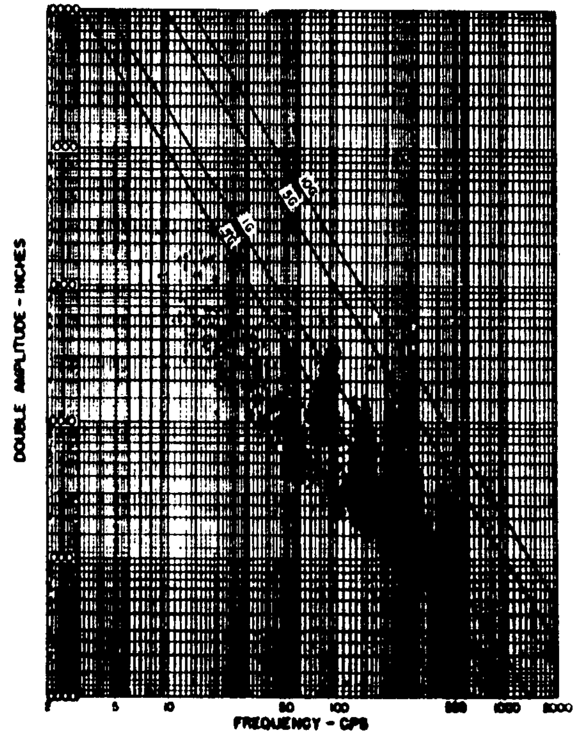

Figure 10. LOCATION: ENGINE

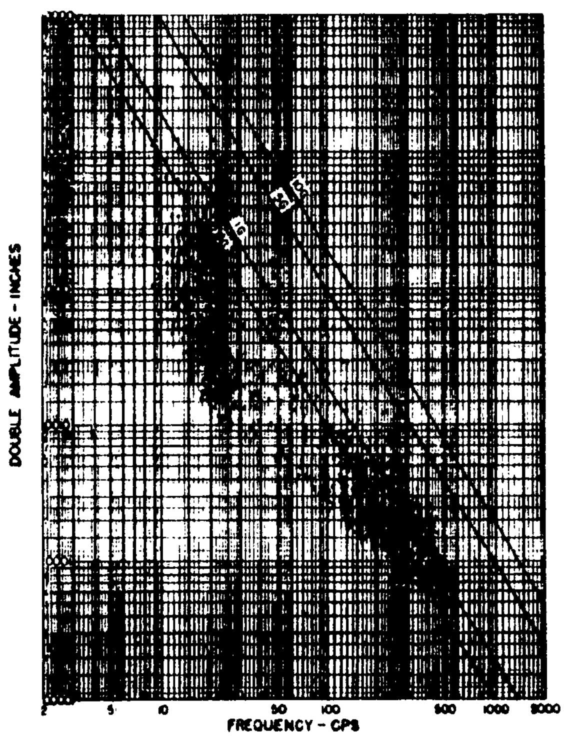

Figure 11. LOCATION: SHOCK MOUNTED EQUIPMENT IN FORWARD QUARTER OF FUSELAGE

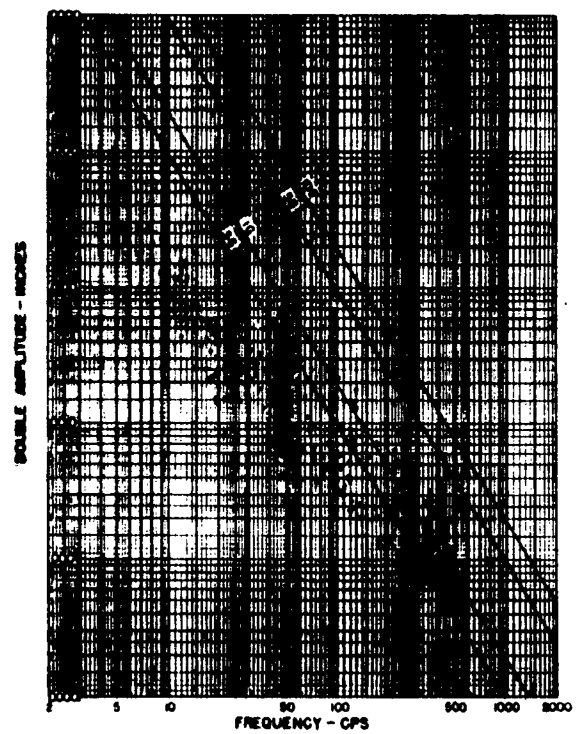

Figure 12. LOCATION: SHOCK MOUNTED EQUIPMENT IN THE CENTER HALF OF FUSELAGE

Figures 9 to 12. Summary Plots for Structural Zones

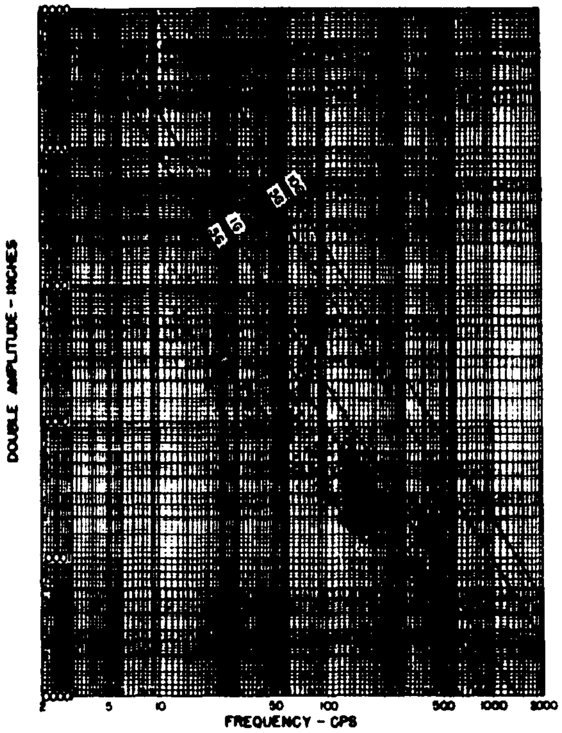

Figure 13.

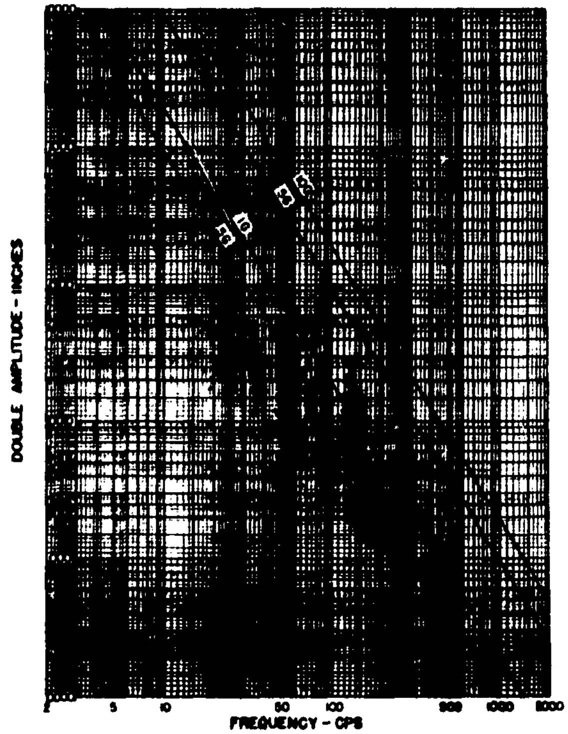

Figure 14.

Figures 13 to 14. Summary Plots for Structural Zones

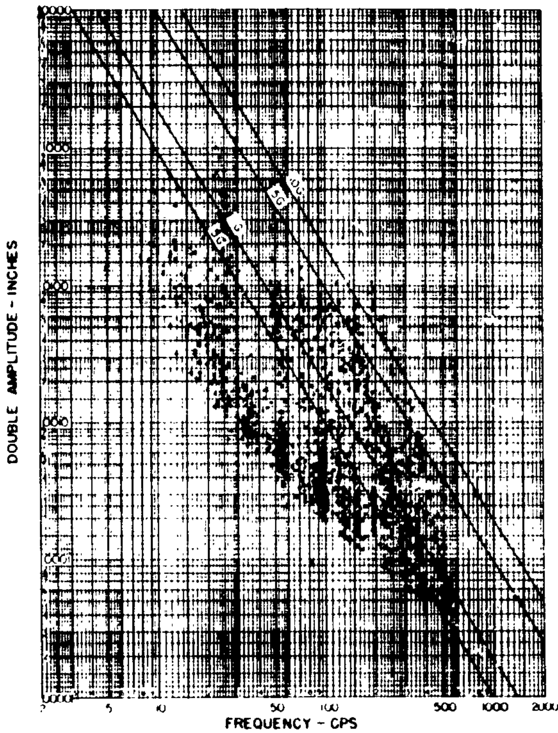

Figure 15. DIRECTION VERT -•, LAT -•, F/A -•
LOCATION NOSE SECTION STRUCTURE, F S 47

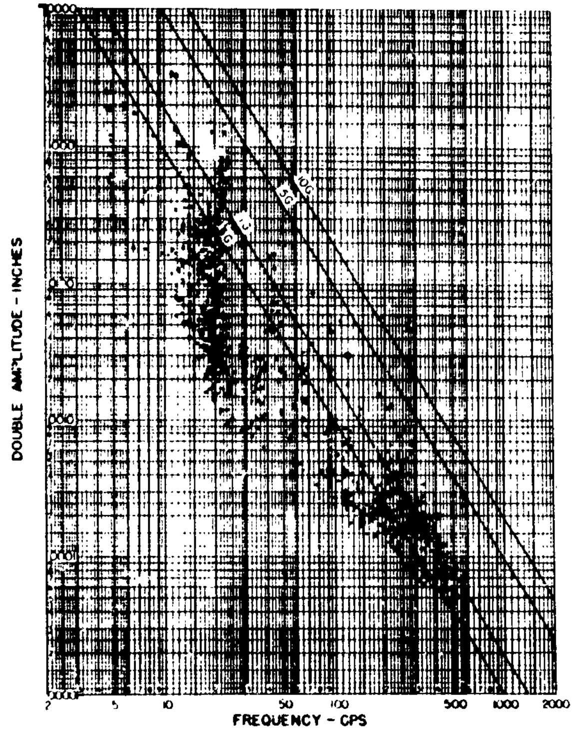

Figure 16. DIRECTION VERT -•, LAT -•, F/A -•
LOCATION TYPE A-4 SIGHT AMPLIFIER (SHOCK MOUNTED), F S 72

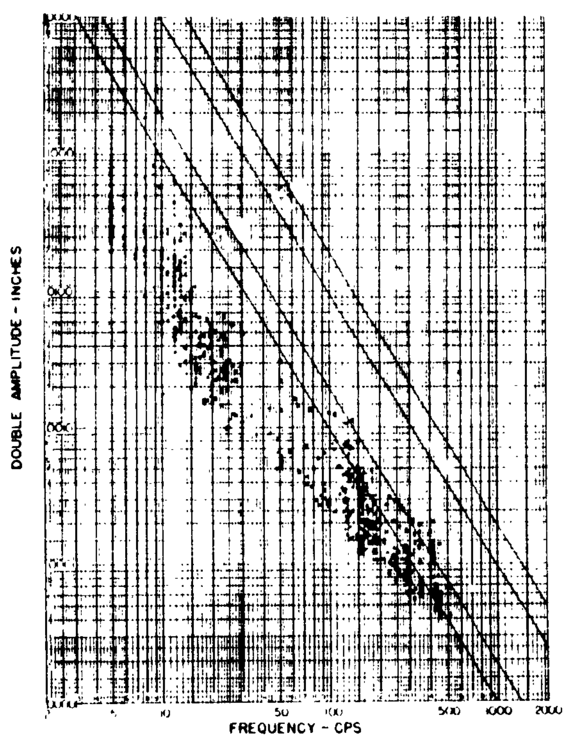

Figure 17. DIRECTION VERT -•, LAT -•, F/A -•
LOCATION RT-263-ARC-34 UNIT (SHOCK MOUNTED), FS 88

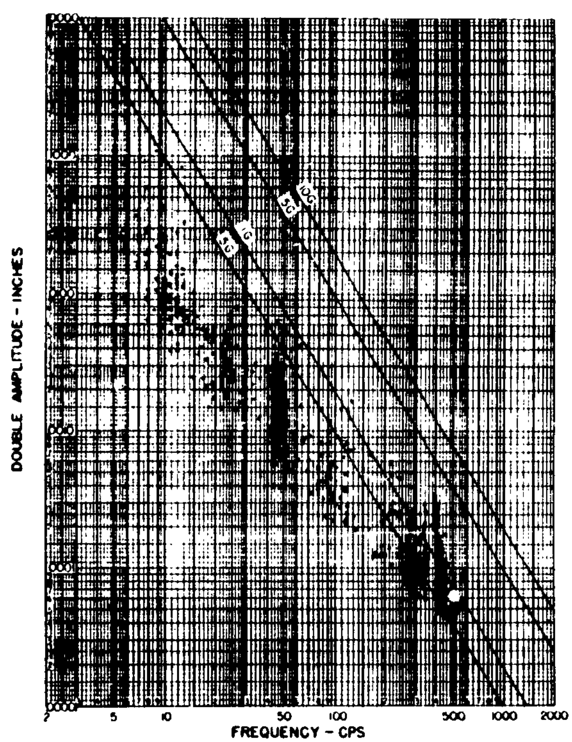

Figure 18. DIRECTION VERT -•, LAT -•, F/A -•
LOCATION INSTRUMENT PANEL, UPPER LEFT SIDE (SHOCK MOUNTED) F S 128

Figures 15 to 18. Summary Plots for Clusters of Two or Three Pickups

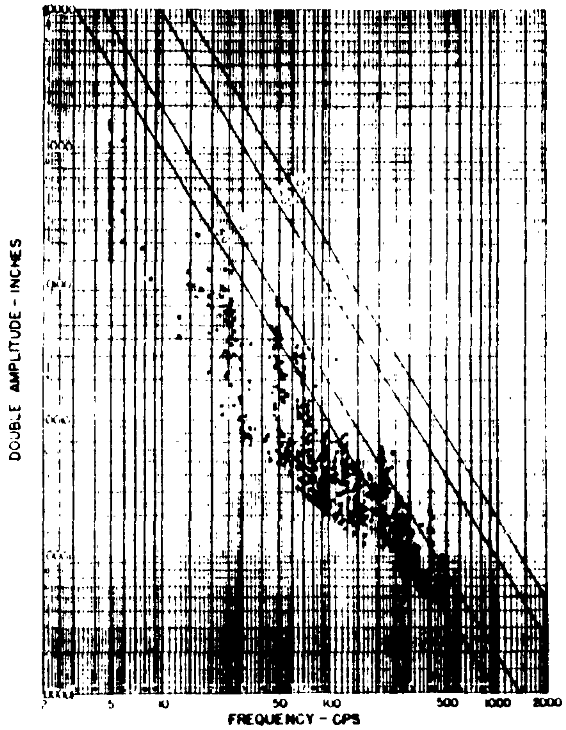

Figure 19. DIRECTION VERT - •, LAT - •, F/A - •
LOCATION STRUCTURE AT BASE OF PILOT SEAT AFT F.S 175

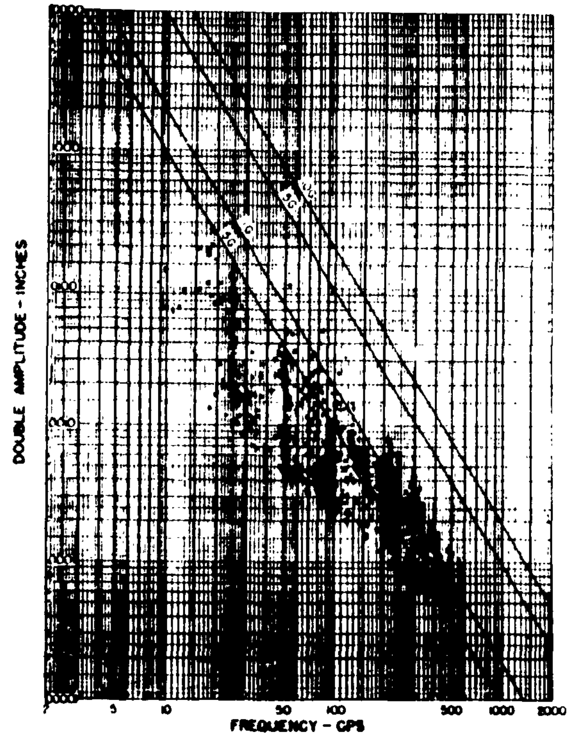

Figure 20. DIRECTION VERT. - •, LAT. - •, F/A - •
LOCATION: STRUCTURE AT BASE OF MAIN INVERTER, F.S. 200

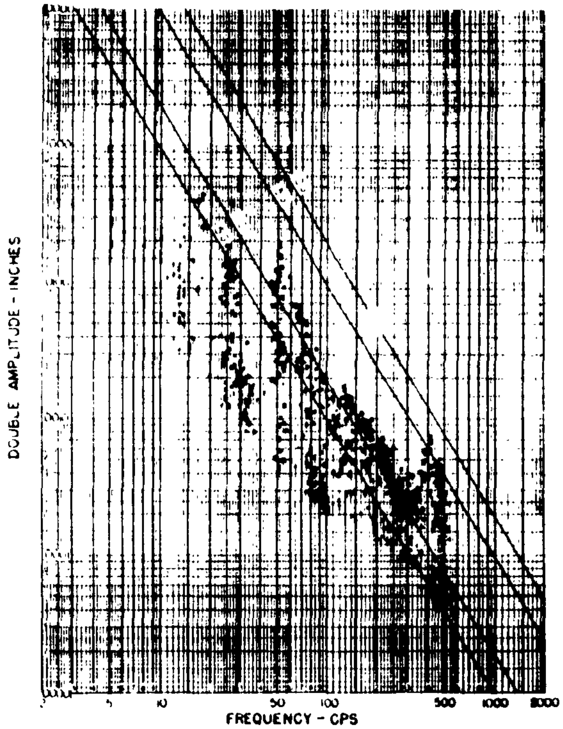

Figure 21. DIRECTION: VERT - •, LAT - •, F/A - •
LOCATION STRUCTURE, LOWER LEFT SIDE F.S 147

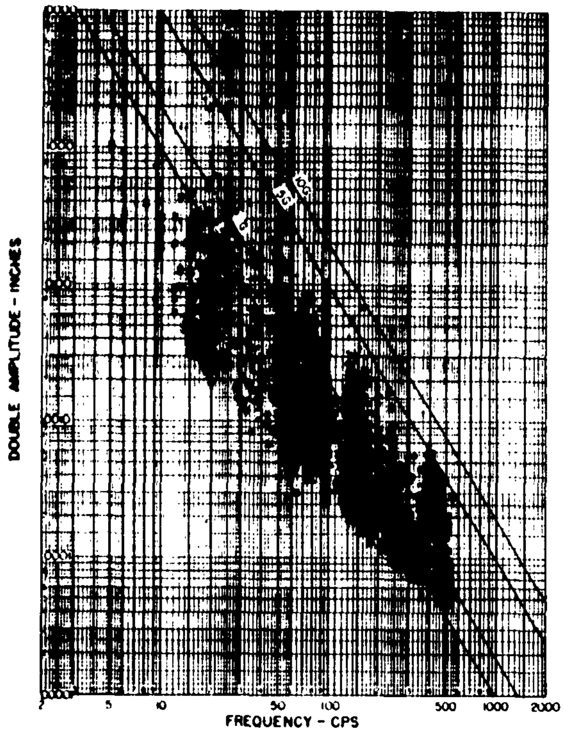

Figure 22. DIRECTION VERT · LAT ○ F/A x
LOCATION LEFT WING TIP

Figures 19 to 22. Summary Plots for Clusters of Two or Three Pickups

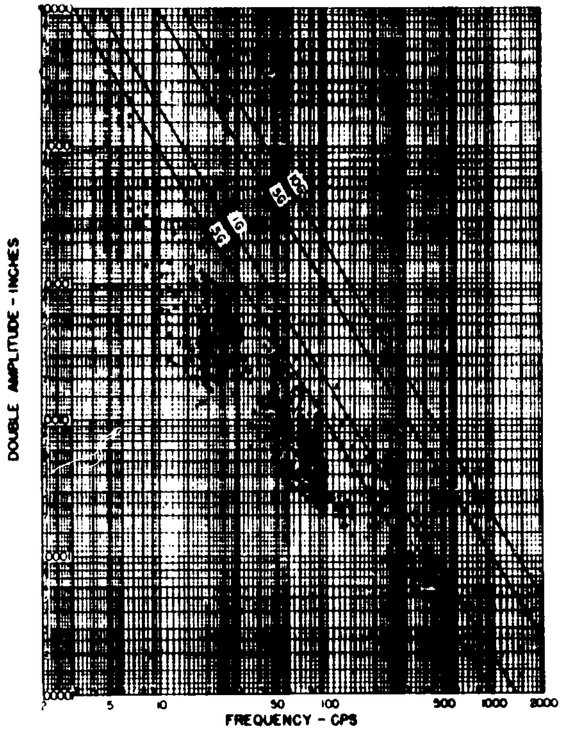

Figure 23. DIRECTION VERT - ·, LAT - ∘, F/A - ◦
LOCATION REAR WING SPAR

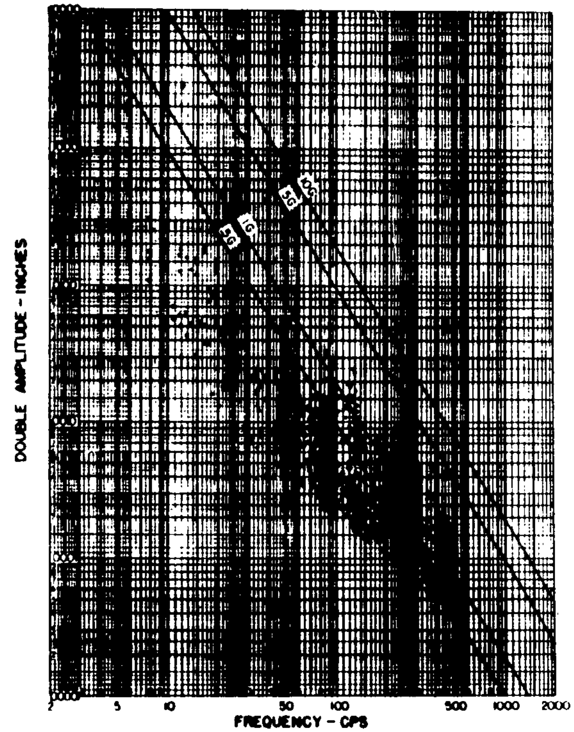

Figure 24. DIRECTION VERT - ·, LAT - ∘, F/A - x
LOCATION STRUCTURE, BOTTOM-CENTER, FS 302

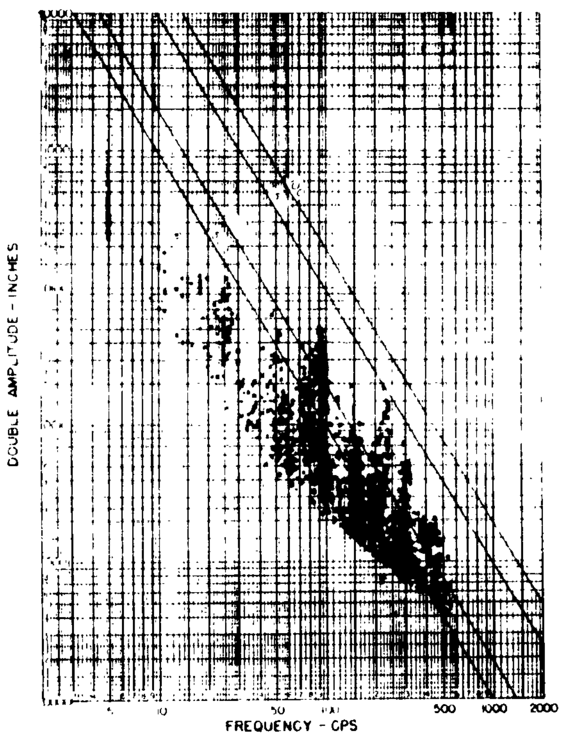

Figure 25. DIRECTION VERT - ·, LAT - ∘, F/A - x
LOCATION STRUCTURE, TOP LEFT SIDE FS 355

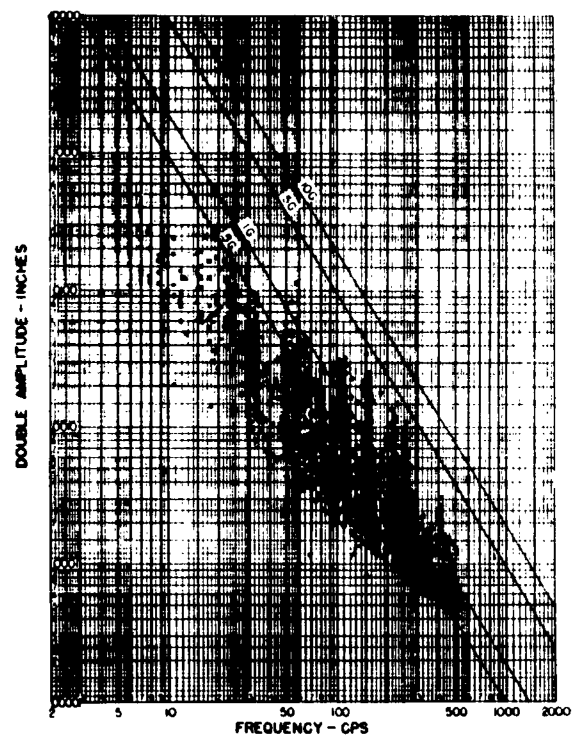

Figure 26. DIRECTION VERT - ·, LAT - ∘, F/A - x
LOCATION STRUCTURE, LOWER LEFT SIDE, F.S. 400

Figures 23 to 26. Summary Plots for Clusters of Two or Three Pickups

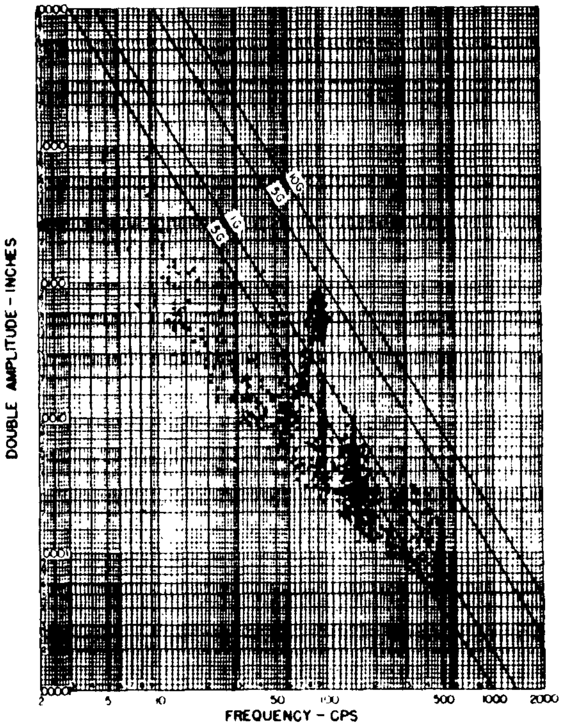

Figure 27. DIRECTION: VERT LAT & F/A
LOCATION: ACCESSORY PAD ON NOSE OF ENGINE

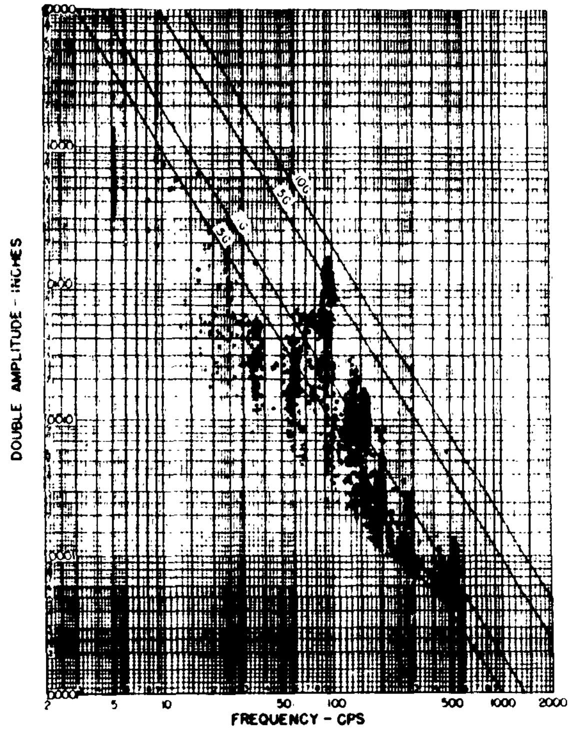

Figure 28. DIRECTION VERT --, LAT - •,
LOCATION BRUSH BAND OF 400A DC GEN

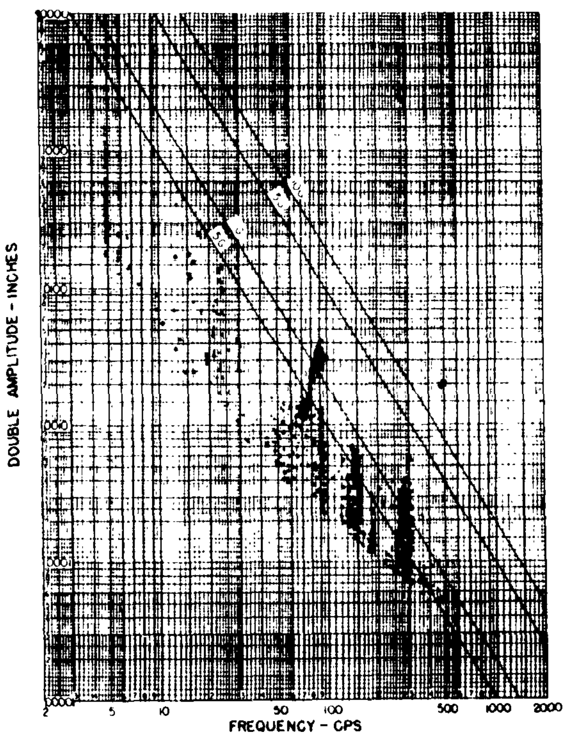

Figure 29. DIRECTION VERT - •, LAT - •,
LOCATION APT END OF ENGINE BURNER SECTION

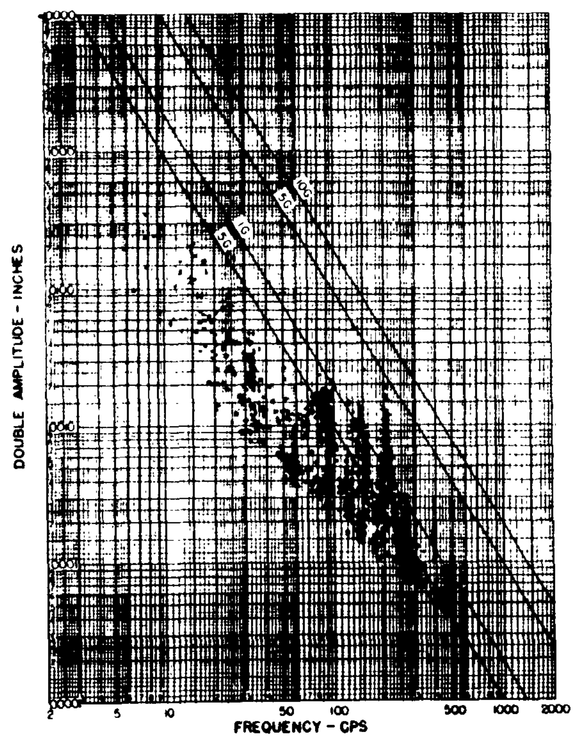

Figure 30. DIRECTION VERT. - •, LAT - •,
LOCATION. FORWARD END OF FORWARD COMPRESSOR SECTION

Figures 27 to 30. Summary Plots for Clusters of Two or Three Pickups

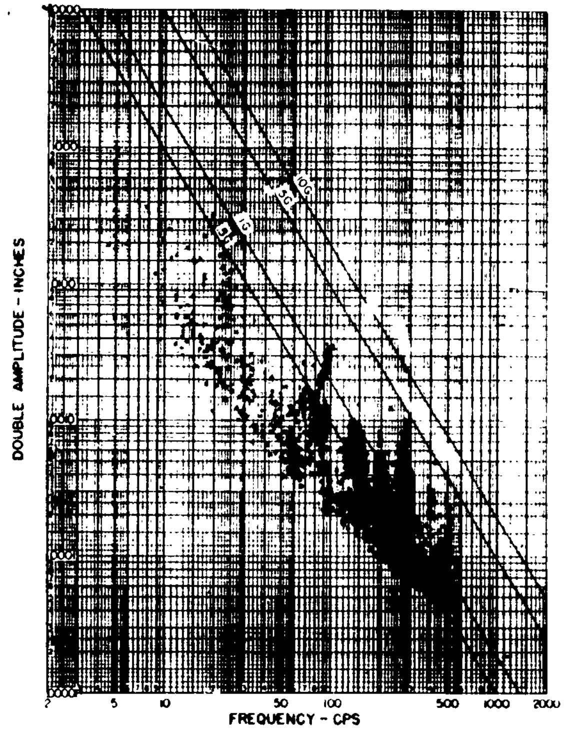

Figure 31. DIRECTION VERT -•, LAT -°, F/A -▪
LOCATION AFT END OF REAR COMPRESSOR SECTION

Figure 31. Summary Plot for Cluster of Three Pickups

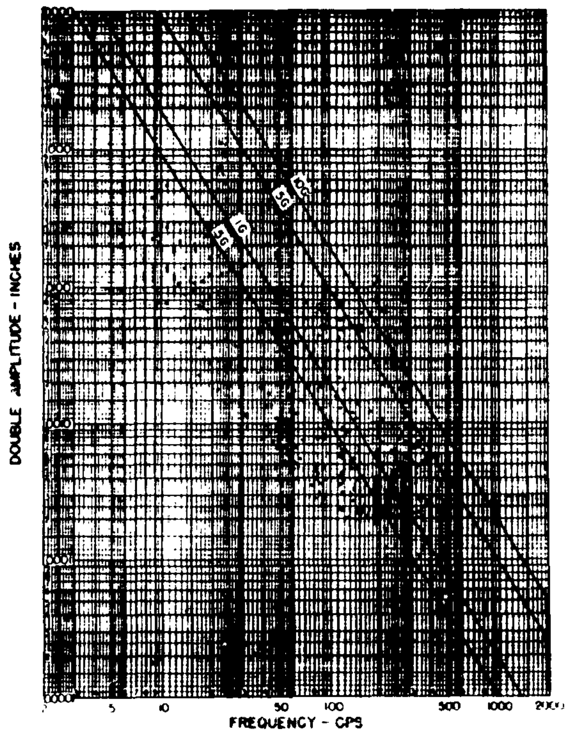

Figure 32. DIRECTION VERT
LOCATION NOSE SECTION STRUCTURE, F.S. 47

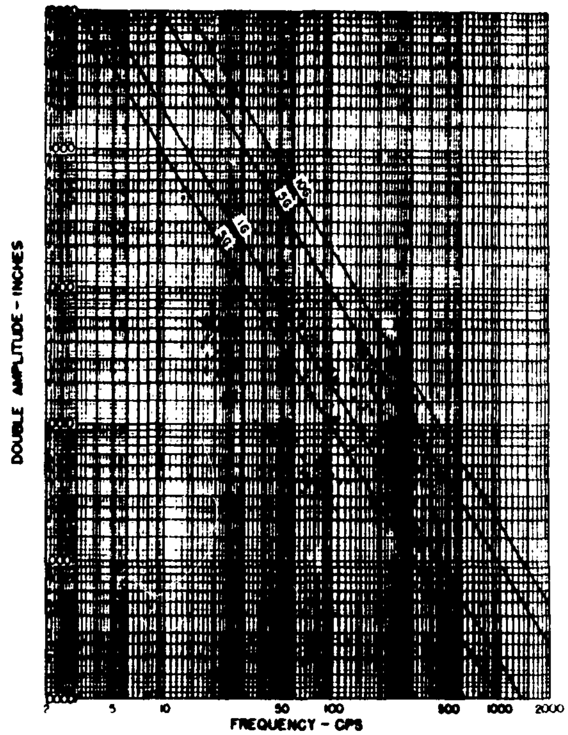

Figure 33. DIRECTION LAT
LOCATION NOSE SECTION STRUCTURE, F.S. 47

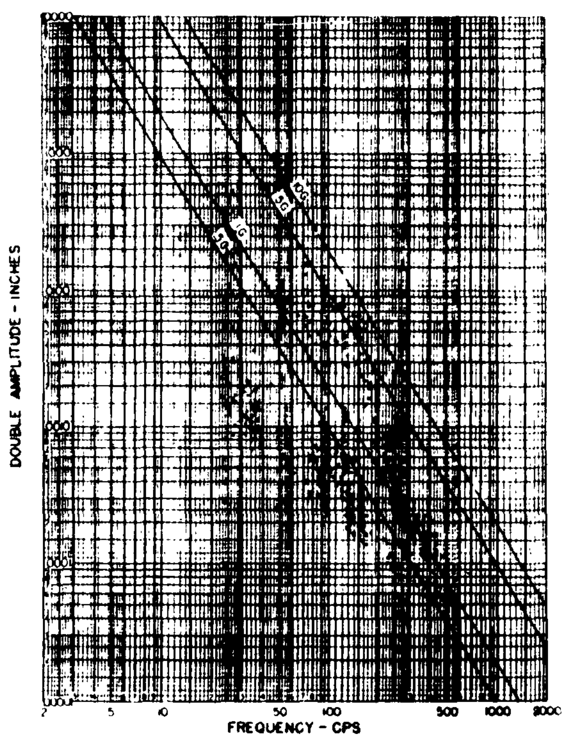

Figure 34. DIRECTION F/A
LOCATION NOSE SECTION STRUCTURE, F.S. 47

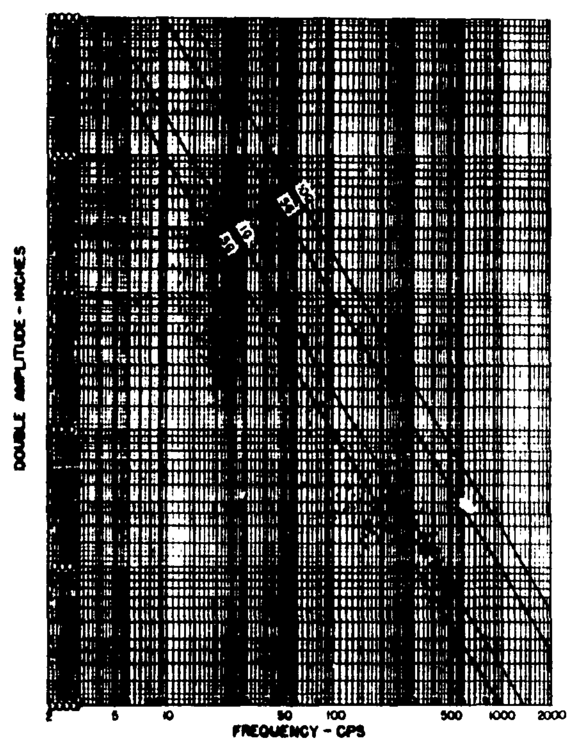

Figure 35. DIRECTION VERT
LOCATION TYPE A-4 SIGHT AMPLIFIER (SHOCK MOUNTED) F.S. 72

Figures 32 to 35. Summary Plots for Individual Vibration Pickups

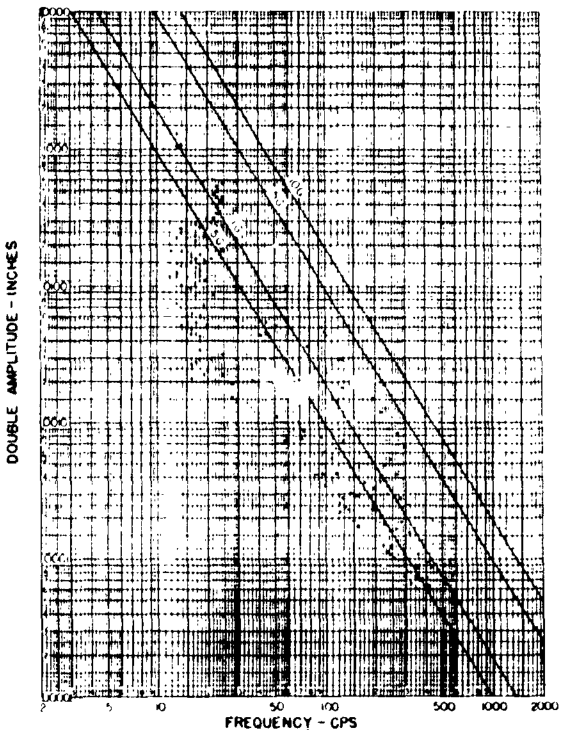

Figure 36. DIRECTION: LAT
LOCATION: TYPE A-4 SIGHT AMPLIFIER (SHOCK MOUNTED)
F.S. 72

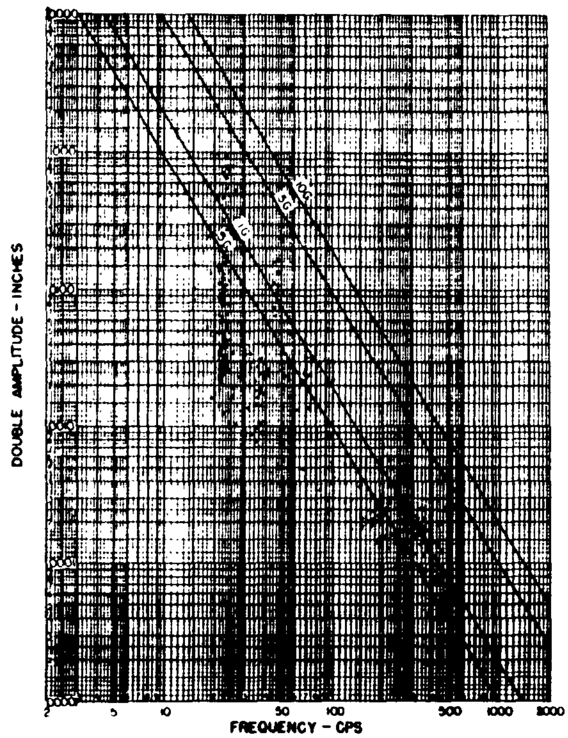

Figure 37. DIRECTION F/A
LOCATION TYPE A-4 SIGHT AMPLIFIER (SHOCK MOUNTED)
F.S. 72

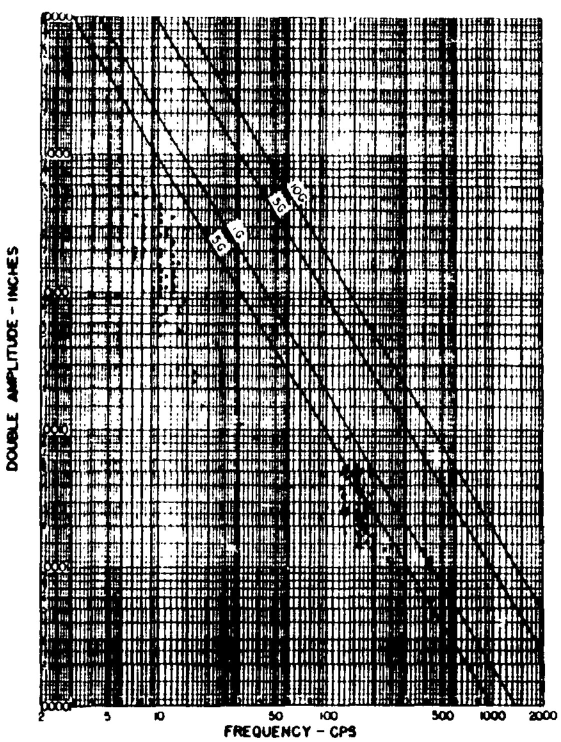

Figure 38. DIRECTION VERT
LOCATION RT-263-ARC-34 UNIT (SHOCK MOUNTED), F.S. 89

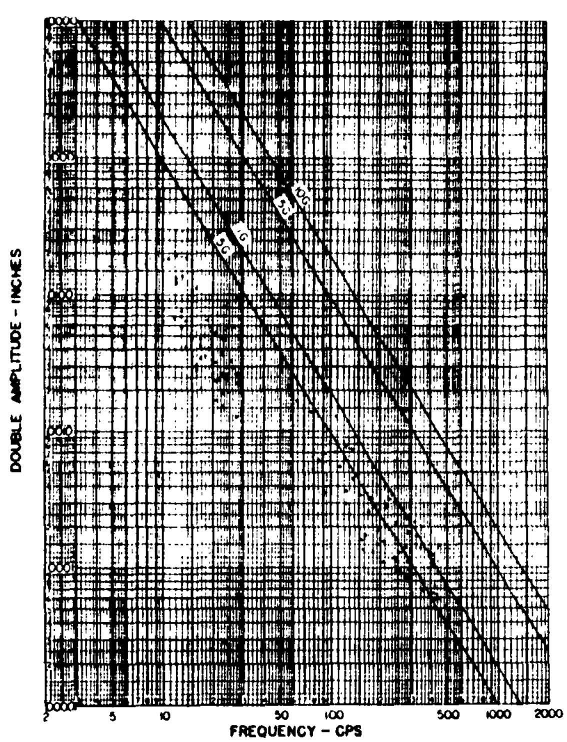

Figure 39. DIRECTION LAT
LOCATION RT-263-ARC-34 UNIT (SHOCK MOUNTED), F.S. 89

Figures 36 to 39. Summary Plots for Individual Vibration Pickups

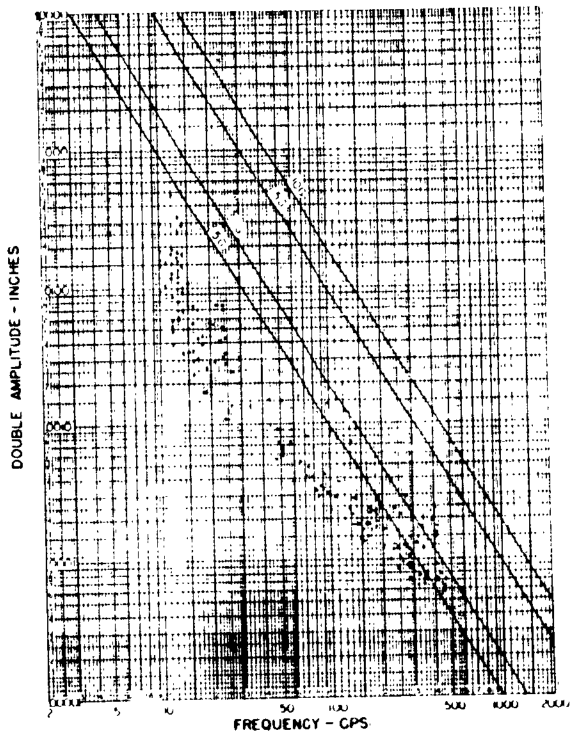

Figure 40. DIRECTION F/A
LOCATION RT-263-ARC-34 UNIT (SHOCK MOUNTED), FS 89

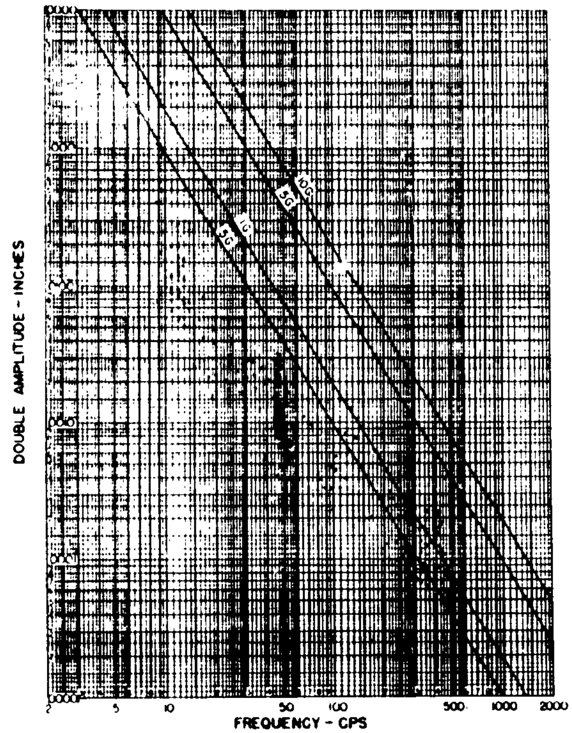

Figure 41. DIRECTION VERT
LOCATION INSTRUMENT PANEL, UPPER LEFT SIDE (SHOCK MOUNTED), F.S. 128

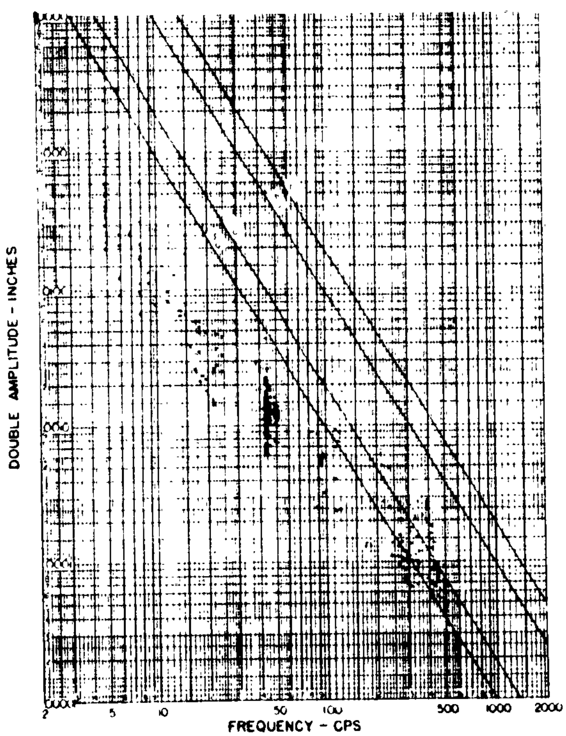

Figure 42. DIRECTION LAT
LOCATION INSTRUMENT PANEL, UPPER LEFT SIDE (SHOCK MOUNTED), F.S. 128

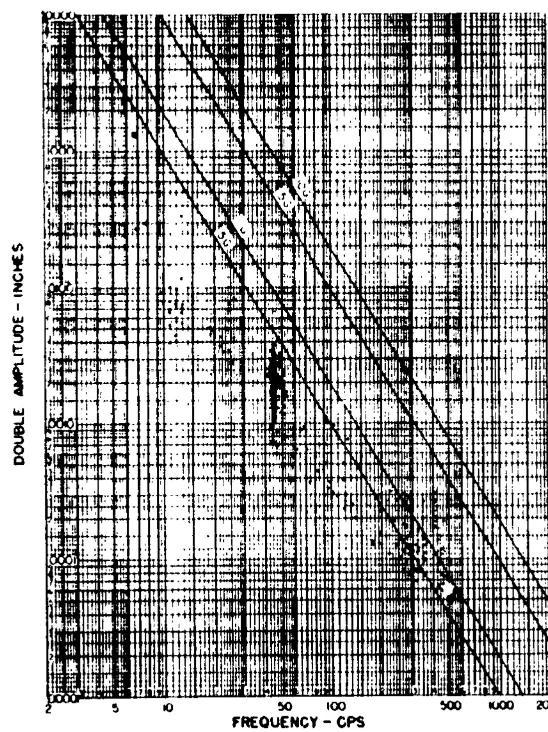

Figure 43. DIRECTION F/A
LOCATION INSTRUMENT PANEL, UPPER LEFT SIDE (SHOCK MOUNTED), FS 128

Figures 40 to 43. Summary Plots for Individual Vibration Pickups

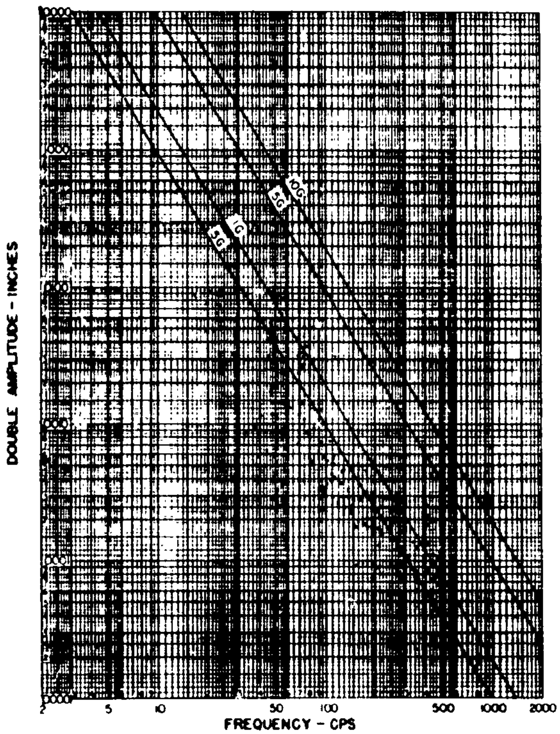

Figure 44. DIRECTION VERT
LOCATION STRUCTURE AT BASE OF PILOT SEAT AFT, FS 178

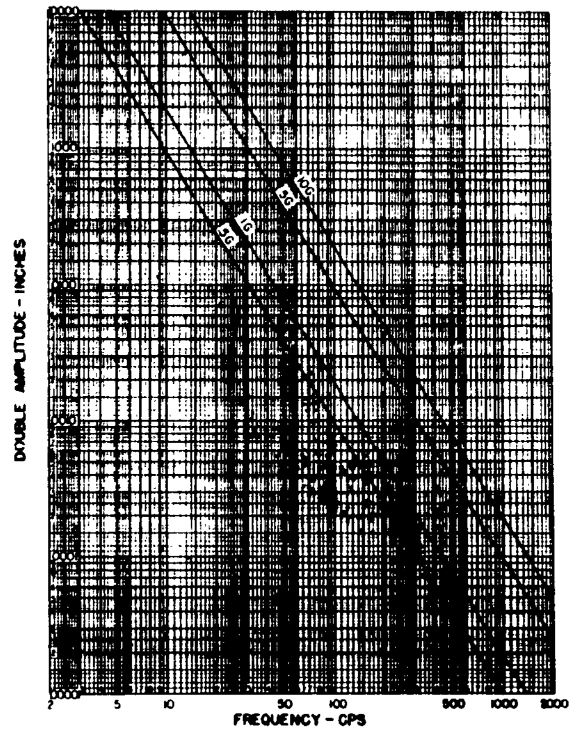

Figure 45. DIRECTION LAT
LOCATION STRUCTURE AT BASE OF PILOT SEAT AFT, F.S 178

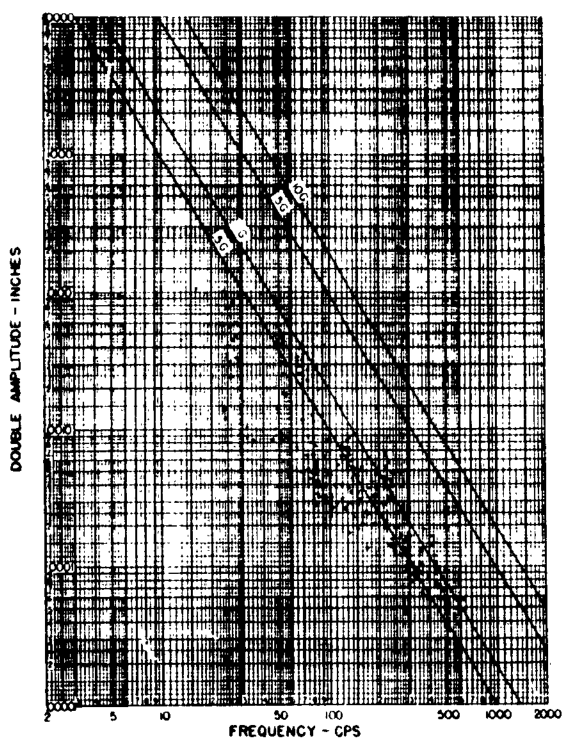

Figure 46. DIRECTION F/A
LOCATION STRUCTURE AT BASE OF PILOT SEAT AFT, FS 178

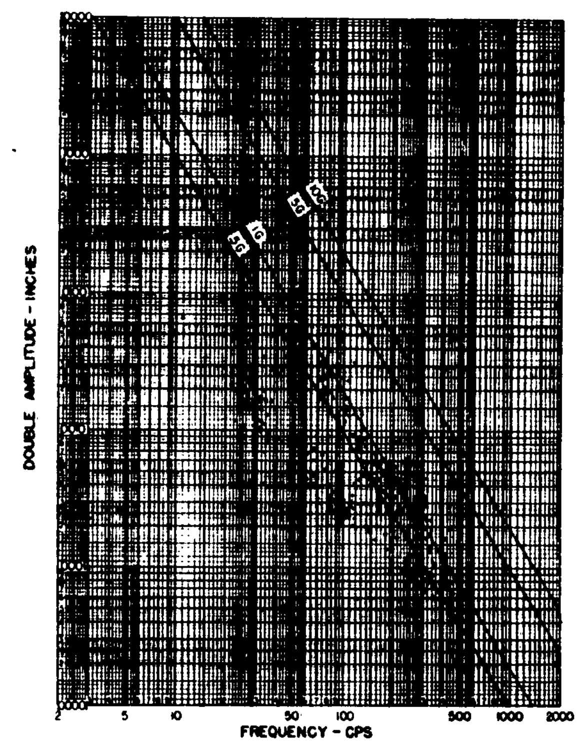

Figure 47. DIRECTION VERT
LOCATION STRUCTURE AT BASE OF MAIN INVERTER, F.S. 200

Figures 44 to 47. Summary Plots for Individual Vibration Pickups

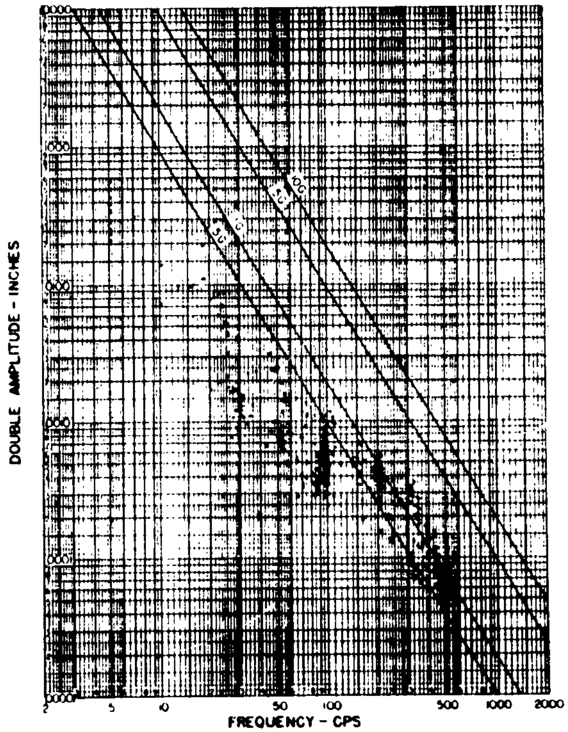

Figure 48. DIRECTION: LAT
LOCATION: STRUCTURE AT BASE OF MAIN INVERTER, F S 200

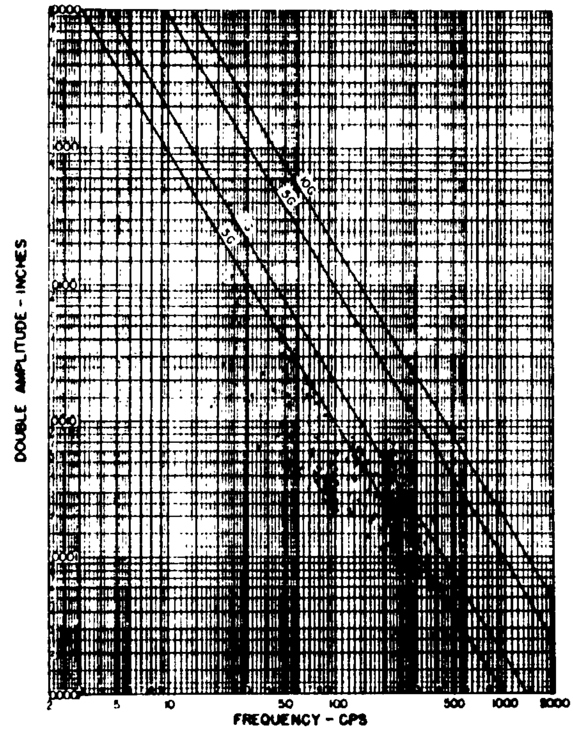

Figure 49. DIRECTION: F/A
LOCATION: STRUCTURE AT BASE OF MAIN INVERTER, F S 200

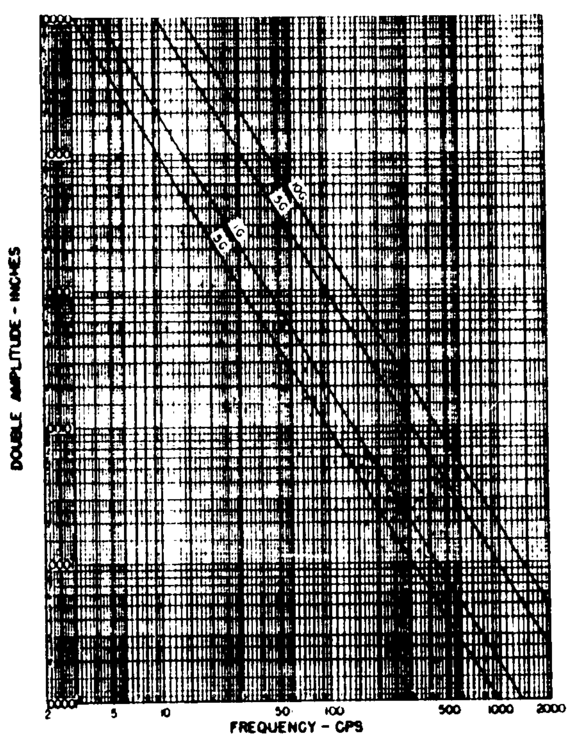

Figure 50. DIRECTION: VERT
LOCATION: STRUCTURE, LOWER LEFT SIDE, F.S 147

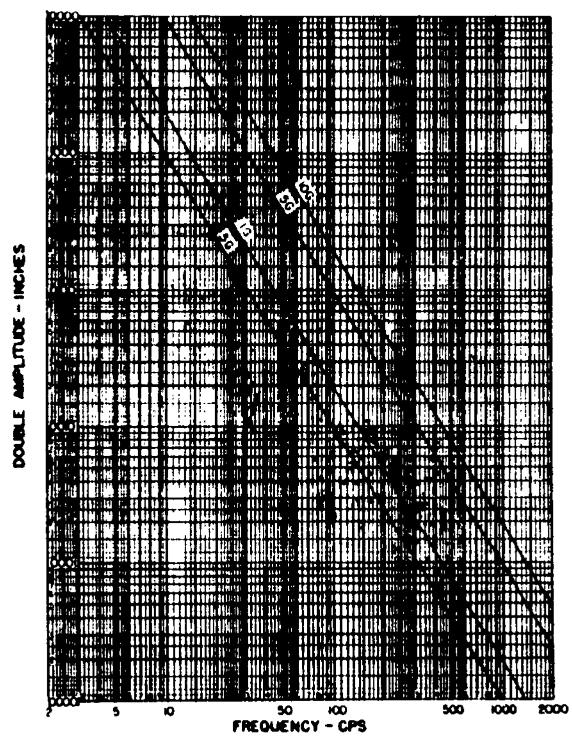

Figure 51. DIRECTION: LAT.
LOCATION: STRUCTURE, LOWER LEFT SIDE, F.S.147

Figures 48 to 51. Summary Plots for Individual Vibration Pickups

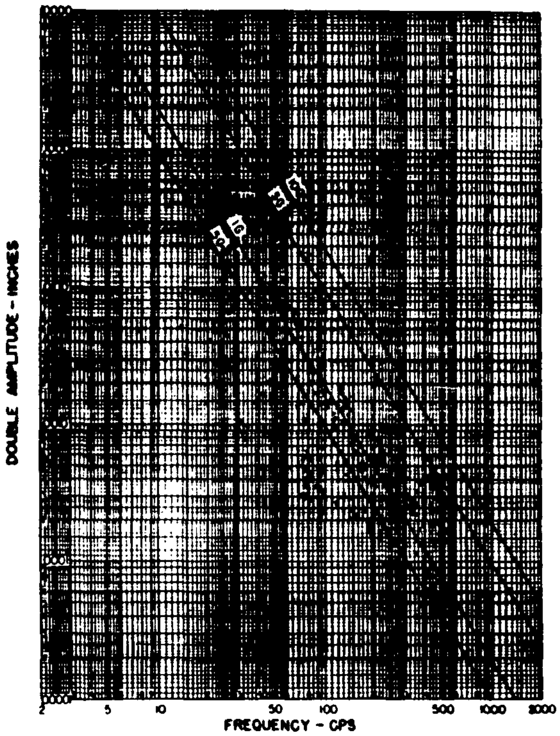

Figure 52.

DIRECTION F/A
LOCATION: STRUCTURE, LOWER LEFT SIDE, F.S. 147

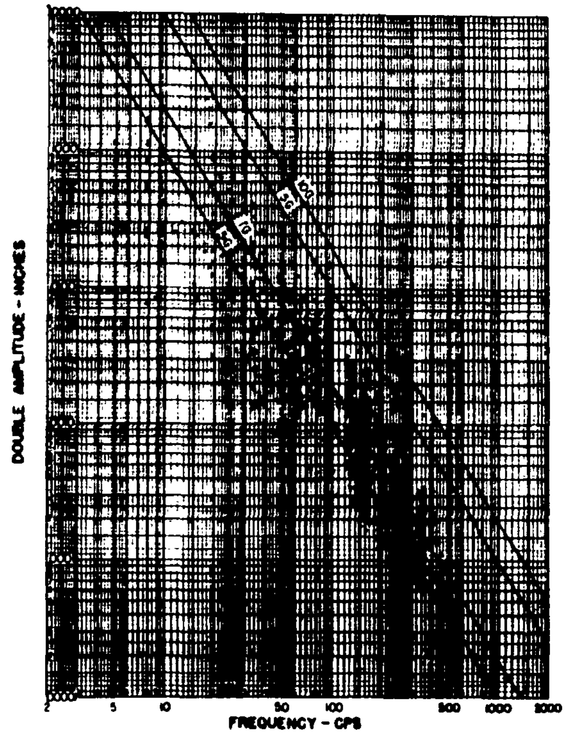

Figure 53.

DIRECTION VERT
LOCATION: LEFT WING TIP

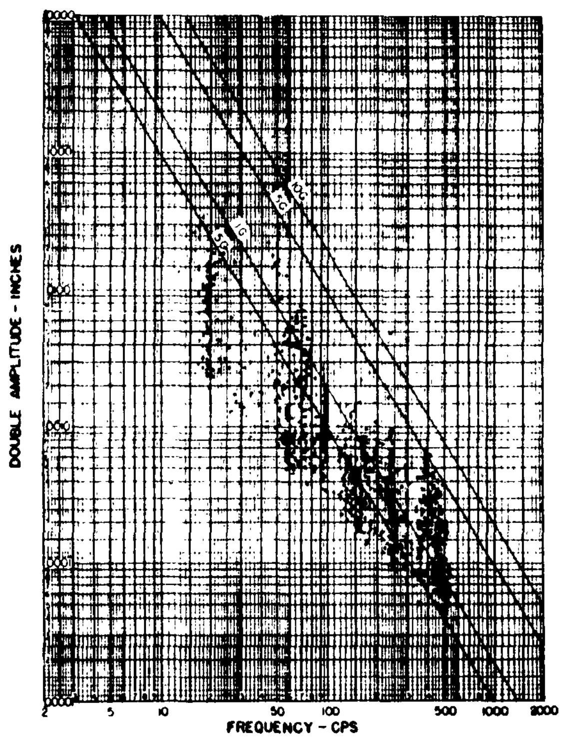

Figure 54.

DIRECTION: LAT
LOCATION: LEFT WING TIP

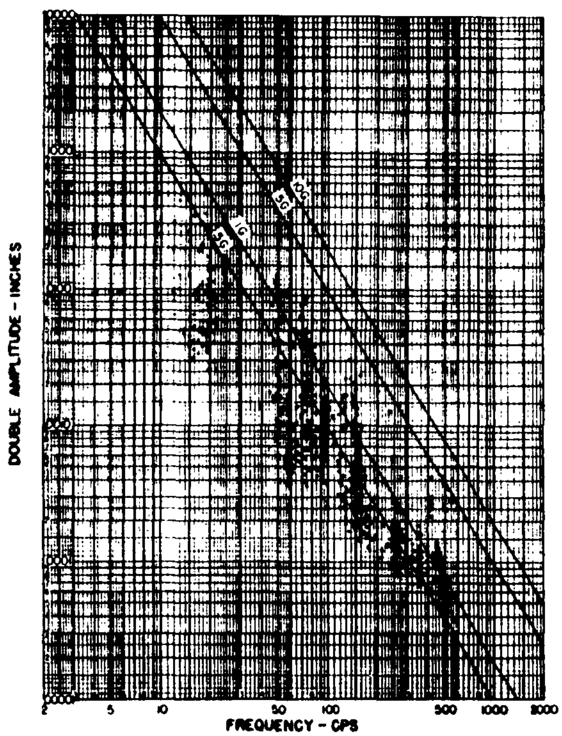

Figure 55.

DIRECTION F/A
LOCATION: LEFT WING TIP

Figures 52 to 55. Summary Plots for Individual Vibration Pickups

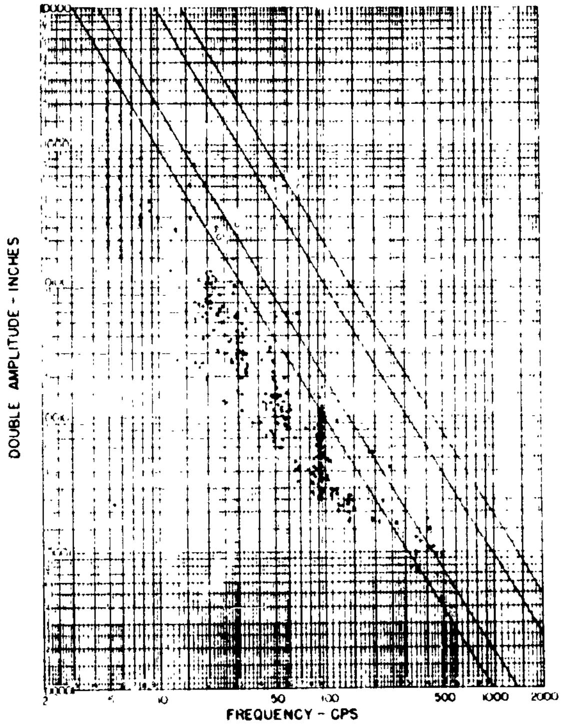

Figure 56. DIRECTION VERT
LOCATION REAR WING SPAR

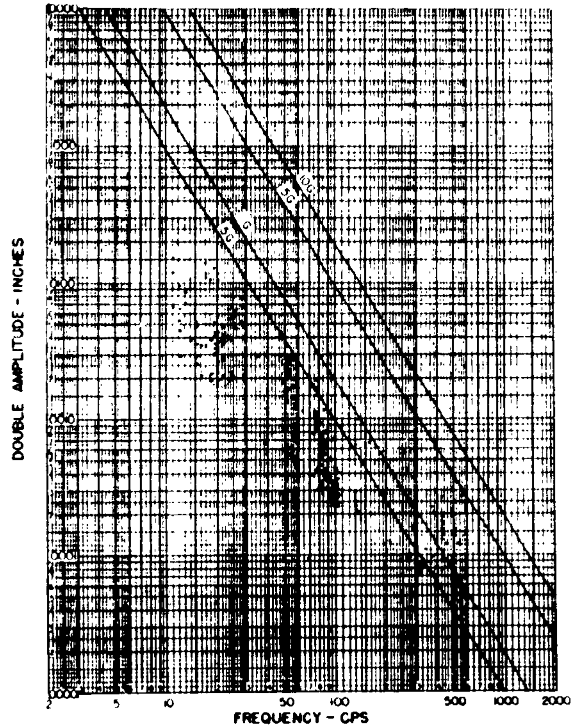

Figure 57. DIRECTION LAT
LOCATION REAR WING SPAR

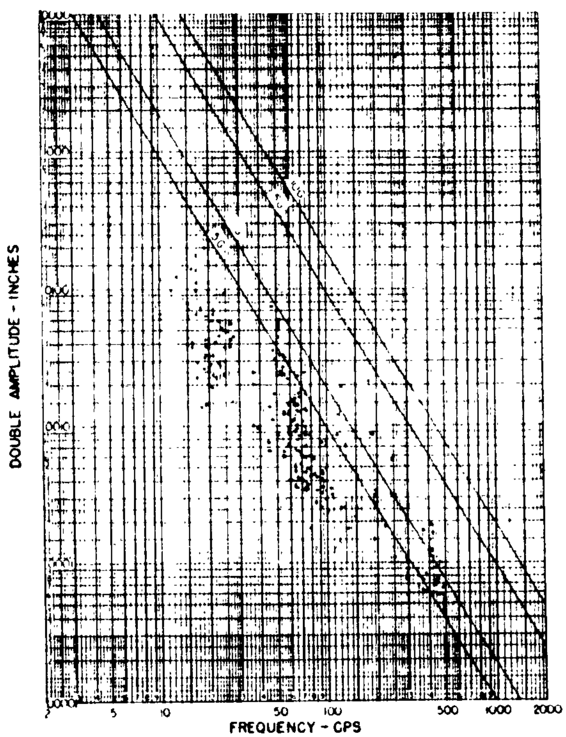

Figure 58. DIRECTION F/A
LOCATION REAR WING SPAR

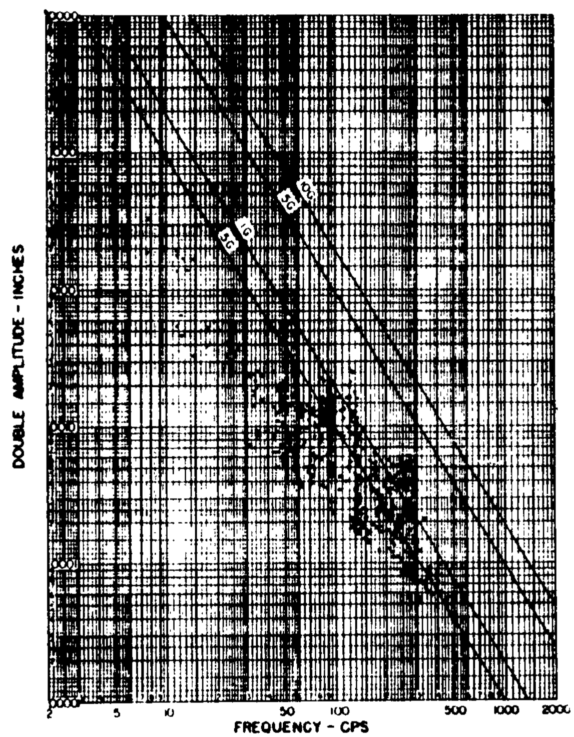

Figure 59. DIRECTION VERT
LOCATION STRUCTURE, BOTTOM CENTER, F.S. 302

Figures 56 to 59. Summary Plots for Individual Vibration Pickups

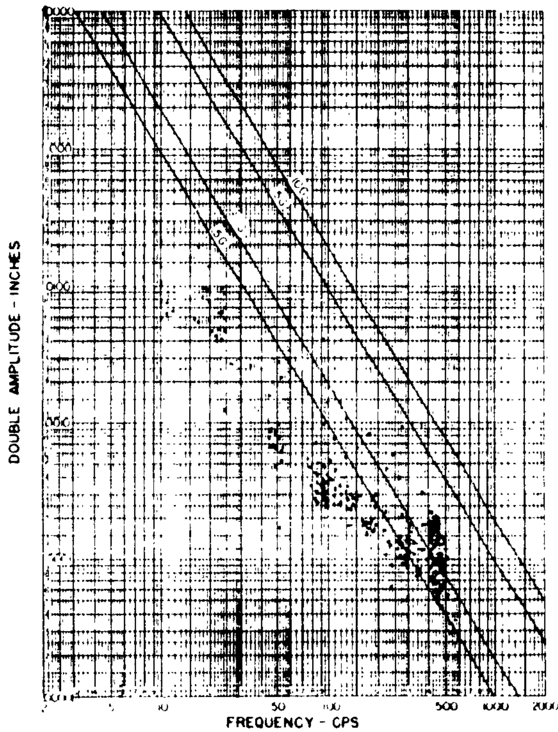

Figure 60. DIRECTION: LAT
LOCATION: STRUCTURE, BOTTOM CENTER, F.S. 302

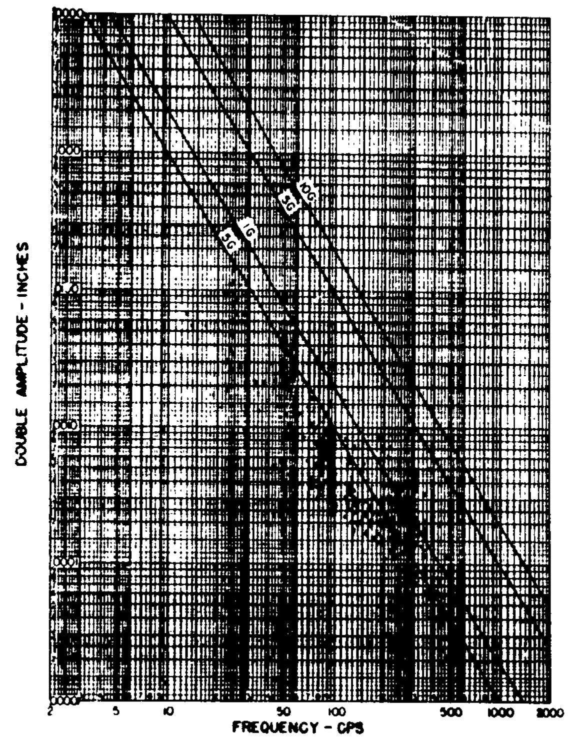

Figure 61. DIRECTION: F/A
LOCATION: STRUCTURE, BOTTOM CENTER, F.S. 302

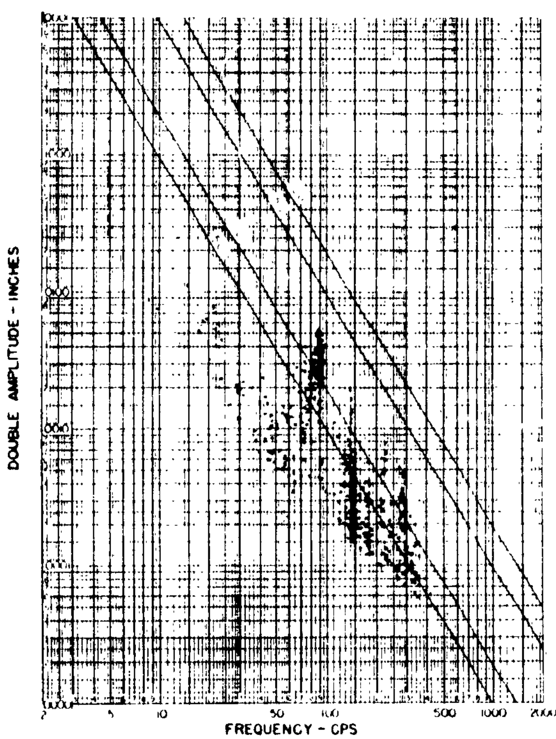

Figure 62. DIRECTION: VERT
LOCATION: STRUCTURE, TOP LEFT SIDE, F.S. 558

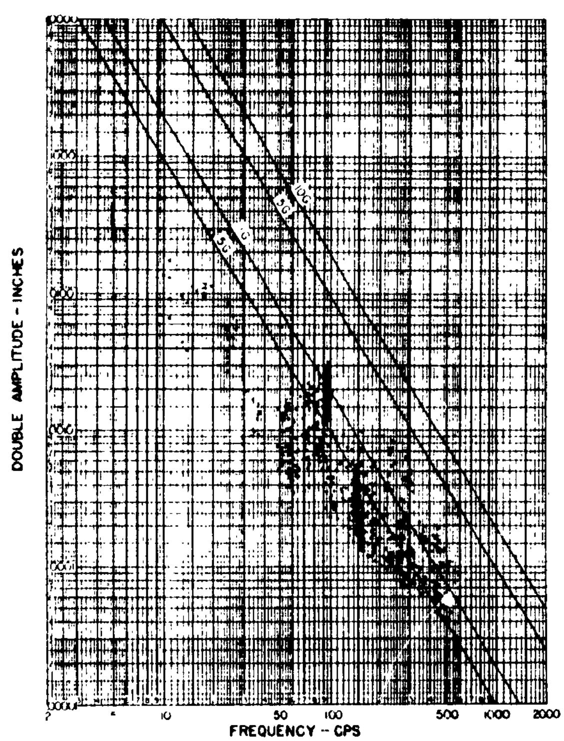

Figure 63. DIRECTION: LAT
LOCATION: STRUCTURE, TOP LEFT SIDE, F.S. 558

Figures 60 to 63. Summary Plots for Individual Vibration Pickups

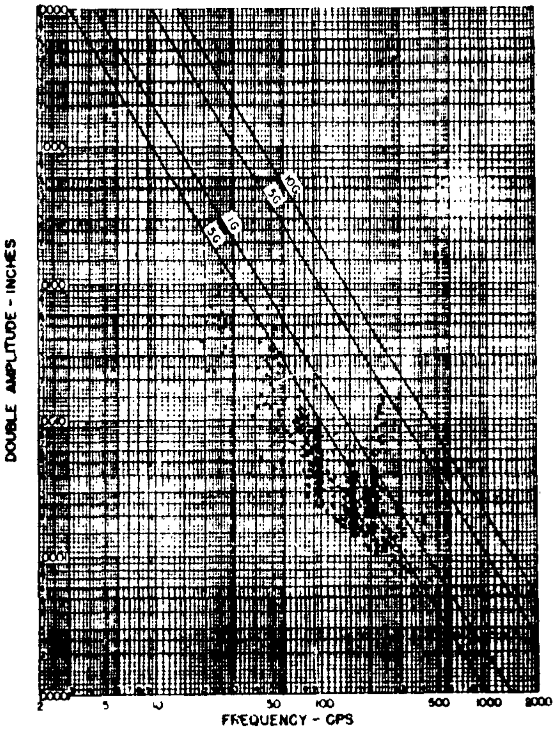

Figure 64. DIRECTION F/A
LOCATION STRUCTURE, TOP LEFT SIDE, F.S 388

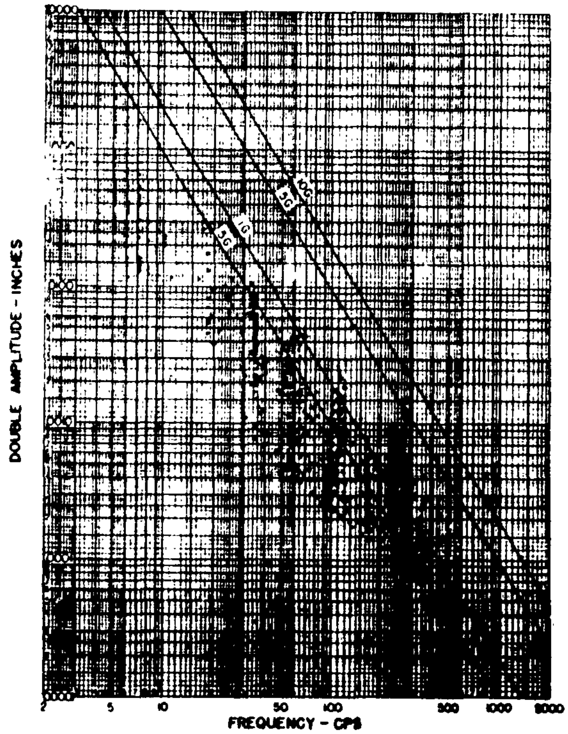

Figure 65. DIRECTION VERT.
LOCATION STRUCTURE, LOWER LEFT SIDE, F.S 490

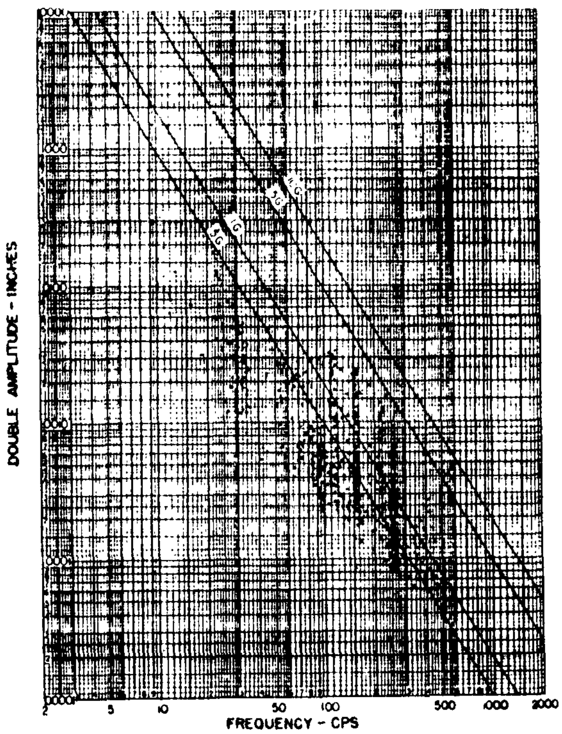

Figure 66. DIRECTION LAT
LOCATION STRUCTURE, LOWER LEFT SIDE, F.S.490

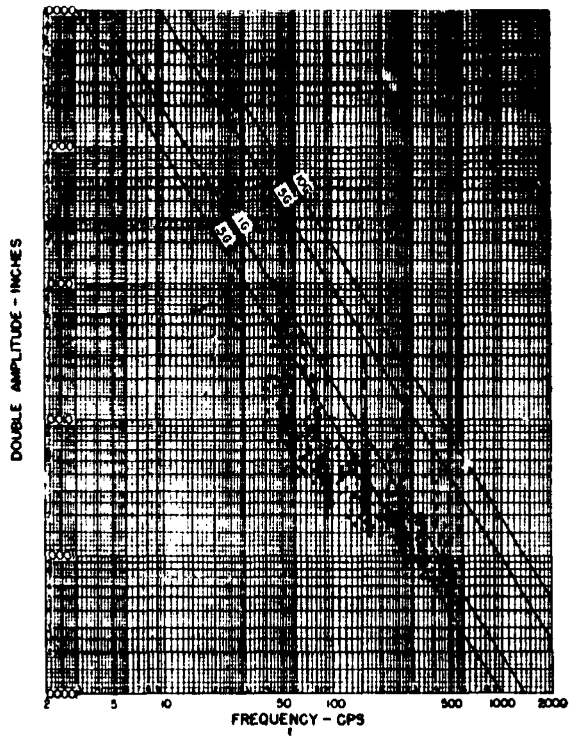

Figure 67. DIRECTION F/A
LOCATION STRUCTURE, LOWER LEFT SIDE, F.S.490

Figures 64 to 67. Summary Plots for Individual Vibration Pickups

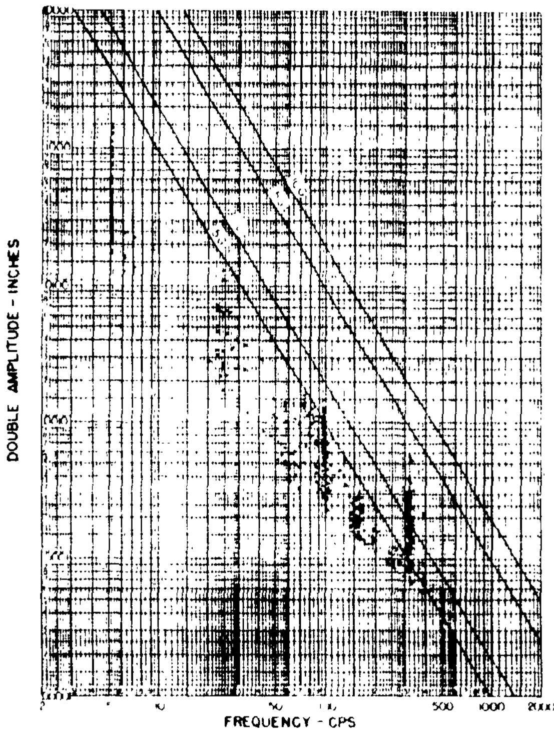

Figure 68. DIRECTION VERT
LOCATION ACCESSORY PAD ON NOSE OF ENGINE

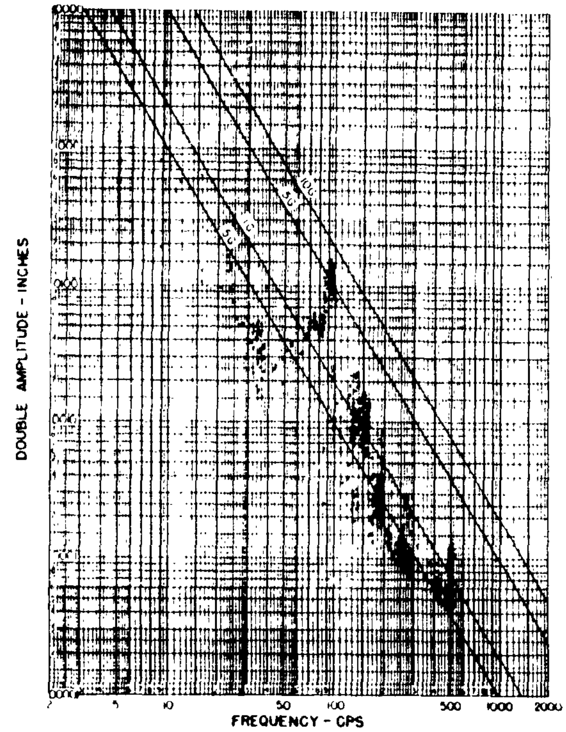

Figure 69. DIRECTION LAT
LOCATION ACCESSORY PAD ON NOSE OF ENGINE

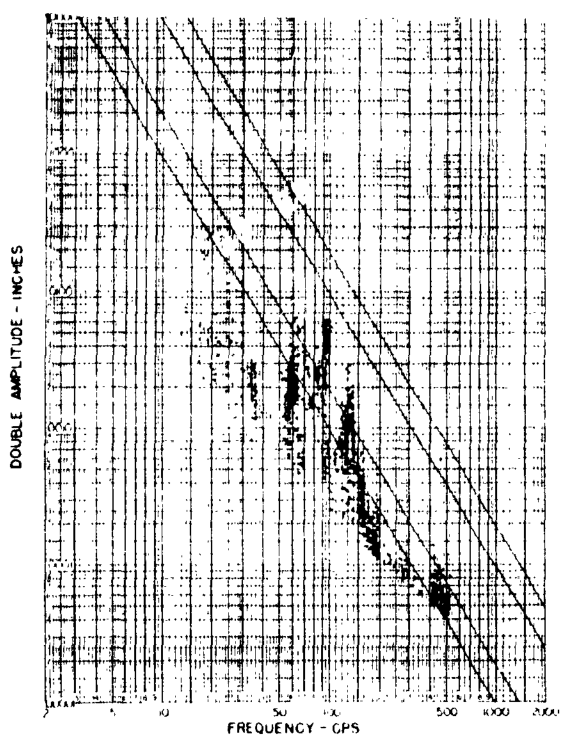

Figure 70. DIRECTION F/A
LOCATION ACCESSORY PAD ON NOSE OF ENGINE

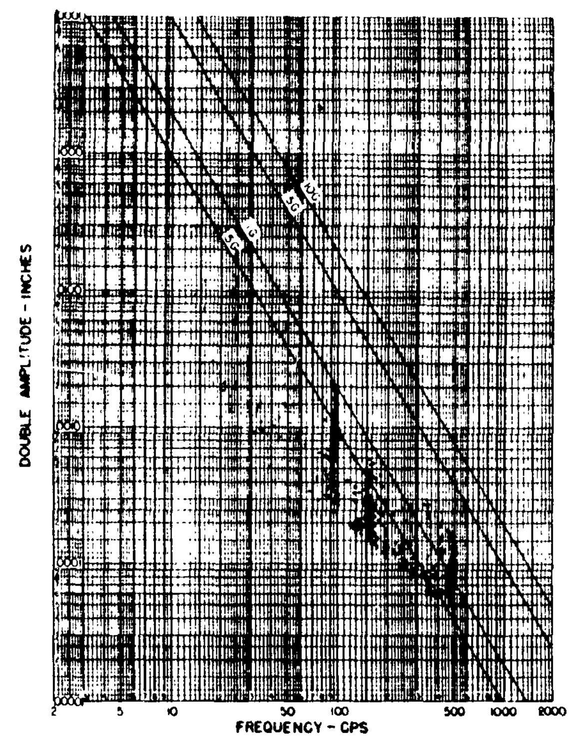

Figure 71. DIRECTION VERT
LOCATION BRUSH BAND OF 400A D.C. GEN

Figures 68 to 71. Summary Plots for Individual Vibration Pickups

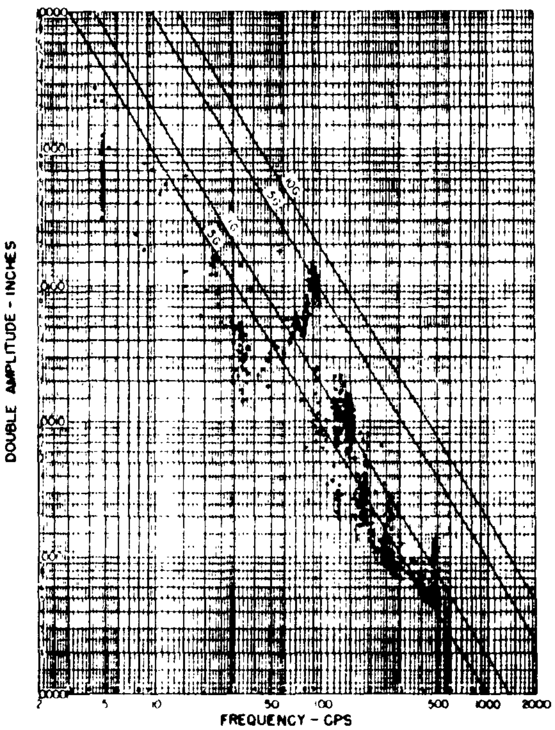

Figure 72. DIRECTION: LAT
LOCATION: BRUSH BAND OF 400A D C GENERATOR, FORWARD END

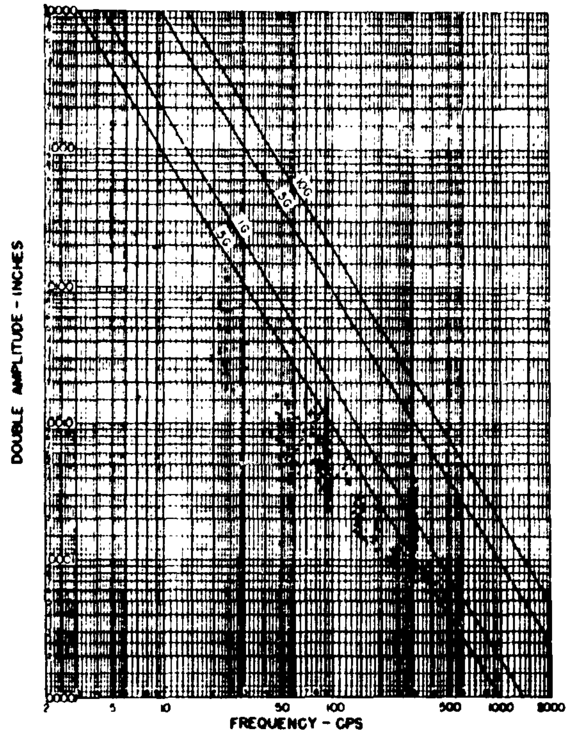

Figure 73. DIRECTION VERT
LOCATION AFT END OF ENGINE BURNER SECTION

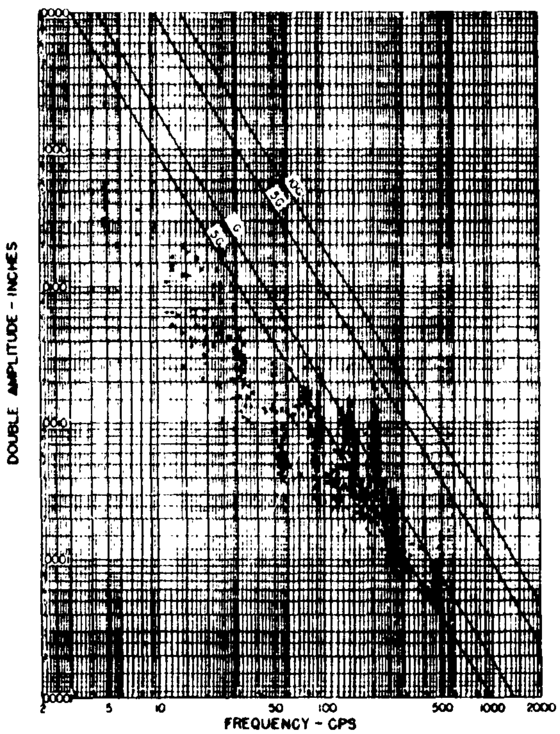

Figure 74. DIRECTION LAT
LOCATION AFT END OF ENGINE BURNER SECTION

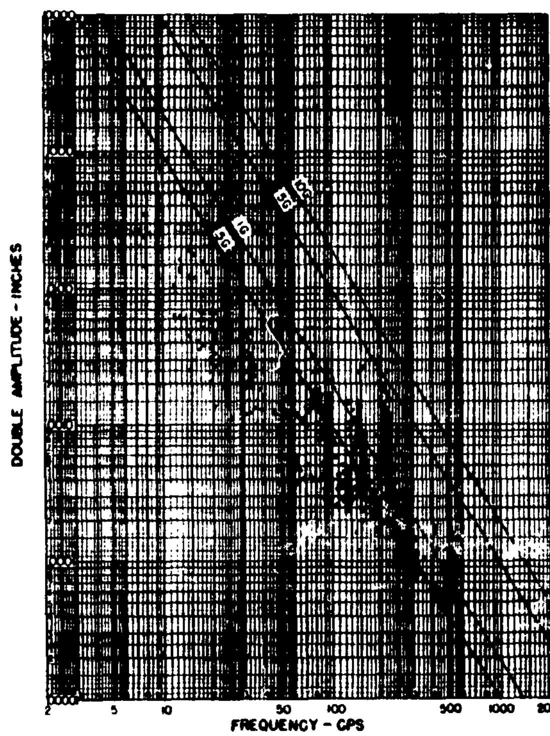

Figure 75. DIRECTION VERT
LOCATION FORWARD END OF COMPRESSOR SECTION

Figures 72 to 75. Summary Plots for Individual Vibration Pickups

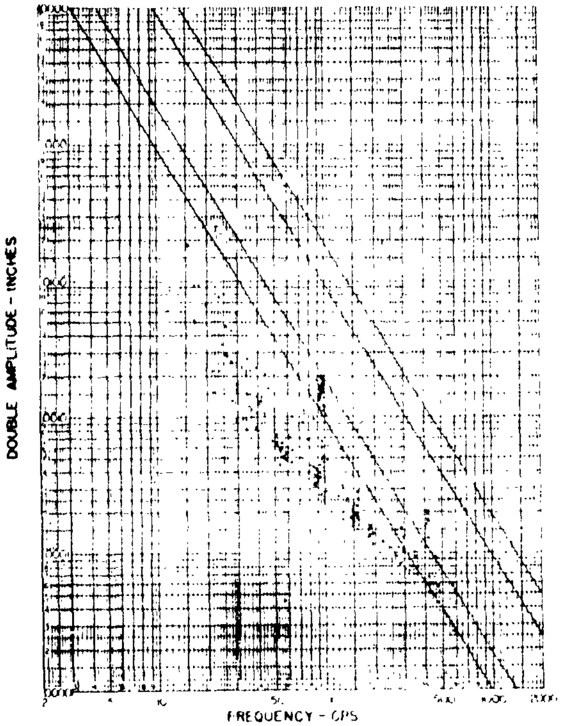

Figure 76. DIRECTION LAT
LOCATION FORWARD END OF FORWARD COMPRESSOR SECTION

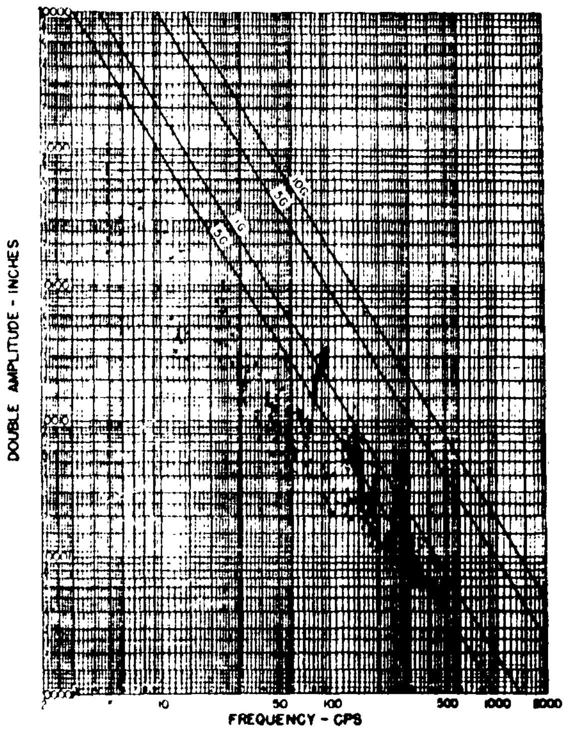

Figure 77. DIRECTION VERT
LOCATION AFT END OF REAR COMPRESSOR SECTION

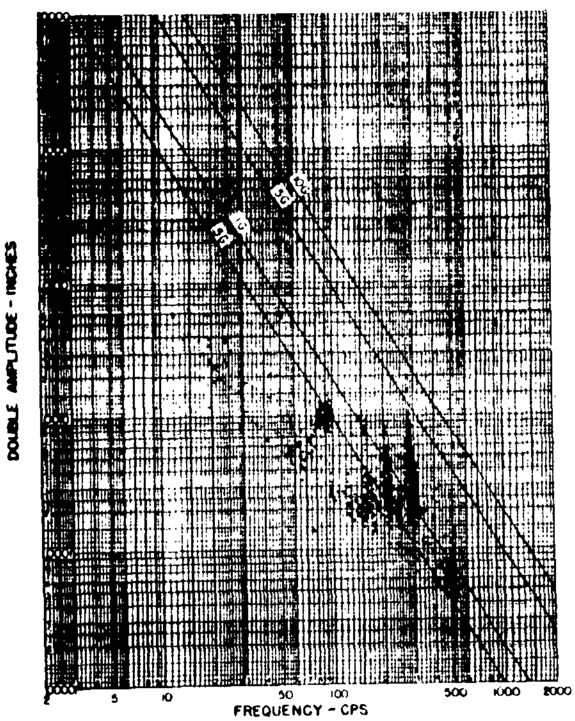

Figure 78. DIRECTION LAT
LOCATION AFT END OF REAR COMPRESSOR SECTION

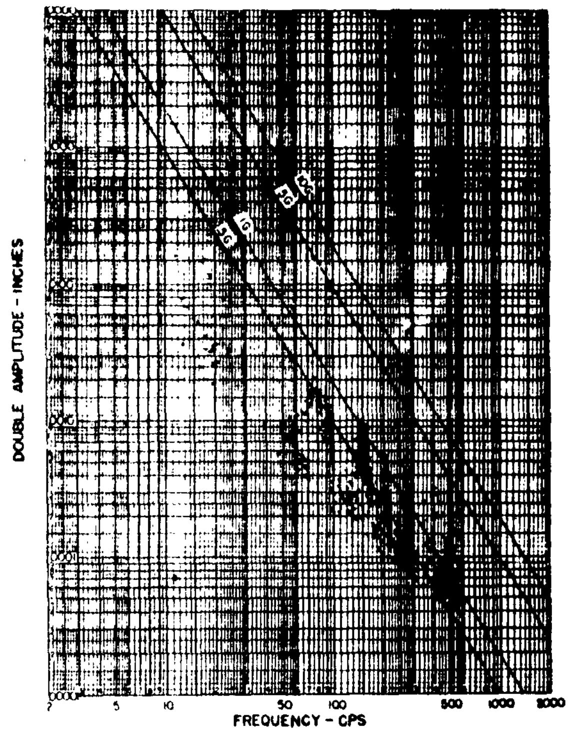

Figure 79. DIRECTION F/A
LOCATION AFT END OF REAR COMPRESSOR SECTION

Figures 76 to 79. Summary Plots for Individual Vibration Pickups

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ONAUTICAL SYSTEMS DIVISION, FLIGHT ENGI-
ERING TEST GROUP, Wright-Patterson Air
rce Base, Ohio, FLIGHT VIBRATION SURVEY OF
00C-1 AIRCRAFT, by Charles E. Thomas,
1961. 37p. incl. figs. and tables.
roject 1309; Task 13004) (WADD TN 61-61)
Unclassified report

F-100C-1 aircraft was surveyed to
termine the vibration environment existing
roughout the vehicle under all flight con-
tions expected in service. Approximately
,053 data points were obtained from 17
erate locations on the vehicle during 17
t flights. The data obtained in this
vey were evaluated to determine the

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ration test requirements which should be
cified for items of equipment to be used
the F-100C-1 aircraft. The data indi-
ed that, in general, the vibration test-
requirements listed in Specification
-E-5272 are more than adequate for
00C-1 equipment, except in the 5 to 24
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AERONAUTICAL SYSTEMS DIVISION, FLIGHT ENGINEERING TEST GROUP, Wright-Patterson Air Force Base, Ohio, FLIGHT VIBRATION SURVEY OF F-100C-1 AIRCRAFT, by Charles E. Thomas, May 1961. 37p. incl. figs. and tables. (Project 1309; Task 13004) (WADD TN 61-61)

Unclassified report

The F-100C-1 aircraft was surveyed to determine the vibration environment existing throughout the vehicle under all flight conditions expected in service. Approximately 34,053 data points were obtained from 17 seperate locations on the vehicle during 17 test flights. The data obtained in this survey were evaluated to determine the

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vibration test requirements which should be specified for items of equipment to be used on the F-100C-1 aircraft. The data indicated that, in general, the vibration testing requirements listed in Specification MIL-E-5272 are more than adequate for F-100C-1 equipment, except in the 5 to 24 cps band.

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Unclassified report

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